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APPLIED MECHANICS REVIEWS

VOL. 6, NO. 2 MARTIN GOLAND *Editor* FEBRUARY 1953

PLASTICS: THEIR MECHANICAL BEHAVIOR AND TESTING

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THE mechanical properties of plastics have been considered of sufficient engineering significance to merit study only within about the past two decades. During this period the chemical industry has synthesized about 30 new types of plastic materials which did not exist before and which have a very wide variety of mechanical properties. The rate of development of new plastics has been so rapid that it has not been possible to keep up with the measurement of their mechanical properties—to say nothing of making thorough studies of the relationship between the mechanical behavior of plastics and their structure and composition, on the one hand, and the effect of conditions imposed by environment and use, on the other hand.

The mechanical properties of most plastics are quite sensitive to several environmental conditions such as ultraviolet light, solvents, and small variations in temperature and humidity which usually do not affect metals and which make testing of plastics more difficult than metals.

In the present article, the current state of knowledge of the mechanical behavior of plastics will be reviewed. While rubber might be considered one type of plastic, and many textiles are made of plastics, the literature in these two fields will not be included in this discussion.

STRESS-STRAIN CHARACTERISTICS AND STATIC STRENGTH

Stress-strain curves of plastics range from the near linear (1)[1] to the nearly continuously curved (2) with most plastics nearest to the latter classification for room-temperature tests. Some plastics (3) show upper and lower yield points like mild steel, and some (4) show a pronounced necking during extension under certain conditions.

The stiffness has been a difficult property to measure from plastics because of the curved stress-strain diagram and nonviscous internal friction. The methods employed—initial tangent (2) and secant (5) from tension or flexure load-deflection curves, velocity of longitudinal oscillations (6), and frequency of steady-state (7) or free vibrations (8, 9)—are not wholly satisfactory because they lack accuracy and reproducibility.

Plastics are usually much more sensitive to time effects at room temperature than metals, so that speed of testing is an important factor in all tests. Several investigators (10–13) have studied the effect of speed of testing on stress-strain behavior of plastics. Because of the significance of speed of testing, special testing machines have been devised to control the rate of loading by means of an inclined table tester (14) or by means of a machine controlled by servomechanism to produce constant strain rate or constant rate of loading (1, 15, 16).

Increases in temperature have been found to reduce markedly the strength and stiffness of most (5, 10, 16a, 17, 18, 19) but not all (5, 19) plastics. These changes may be permanent, due to evaporation of constituents or chemical changes. Exposure to low temperatures usually increases the strength and stiffness (20), may reduce ductility markedly, and may produce irreversible changes such as crystallization and freezing of water and plasticizer (21).

Variations in strength within a sheet of laminate (22, 23) have been studied, as well as the effect on strength of fungus attack (24), biaxial stress (25), and orientation of polymer chains (26). The mechanics of the widely used flexure test has been examined (23).

DUCTILITY AND BRITTLENESS

Plastics range from very brittle to very ductile, but the strain energy absorbed per unit volume up to fracture is quite small compared to that of ductile metals since the strong plastics are, as a rule, brittle and the ductile plastics are usually weak compared to metals. Thus the combination of ductility with strength that produces high energy absorption is seldom found. Because of these facts, impact testing of plastics has been both important and difficult and has received special study (27, 28, 28a). Special machines and techniques have been devised in attempts to solve this problem, such as the guillotine machine (29), the ski-ball machine (30), and others (31).

As the temperature is lowered, it has been found that a temperature is reached at which ductile plastics become brittle. This brittleness temperature has received considerable attention (32, 33). The effect of low temperature on impact strength of thermosetting plastics has been reported (33a).

DAMPING AND DYNAMIC MODULUS

In the damping tests which have been made on plastics, the damping and the "dynamic modulus" have been calculated from

[1] Numbers in parentheses indicate References listed at end of the paper.

(a) resonant frequency and energy input in forced vibrations (7, 34–36), (b) frequency and logarithmic decrement of free vibration of pendulums, reeds, or spring-mass systems (8, 9, 37), (c) resonant frequency and band width in forced vibrations (37), (d) acoustic velocity and attenuation (37, 38), and (e) direct measurement of damping force by balancing out the signal from the elastic force (38a, 38b).

Representation of linear damping by means of the complex variable has been described (39, 40, 78) and referred to as complex damping and complex modulus. Stress-strain relations with damping have been expressed in terms of a memory function (40a).

Various terms are used to describe the results of damping tests, but all have been computed by the use of equations based on the assumption of linear elasticity and linear viscous damping. Since the behavior of most plastics is not accurately represented by either of these assumptions, the results of such computations are of questionable reliability. A more accurate representation of the nonlinear behavior of plastics may yield a more satisfactory determination of damping. Solutions of the type recently presented (41) may prove useful. A realistic theory of damping based on molecular properties, kinematics, and kinetics is needed.

A large increase in dynamic modulus with increase in mean strain has been reported for polyethylene at different temperatures (6).

FATIGUE

While fatigue failure is perhaps of less importance in plastics than in metals, the subject may deserve more attention for scientific reasons than it has received. Fatigue failure being very localized is intimately related to internal structure and structural defects of the material, and so may be an important tool for investigating the contribution of structure to the mechanical behavior of plastics.

Fatigue testing (42) of plastics (43) is complicated by the facts that most plastics are sensitive to small changes in temperature, and that the high damping and low thermal conductivity cause a substantial rise in temperature (11, 44, 45) during vibration. A further complication when the plastic contains fibrous fillers arises from the fact that the fibers tend to retard the propagation of cracks (45).

The fatigue strength has been determined at room temperature for several unfilled (3, 11, 16a, 46) filled (47–52), and laminated (2, 16a, 45, 53–56) plastics. The effect of notches has also been examined for such materials (2, 3, 45, 49, 50). Fatigue notch factors observed ranged from 2.1 to 0.8 and depended markedly on the number of cycles at which the fatigue strengths were determined. The effect of temperature has been studied for fatigue of several laminates (2, 16a, 45, 56). Results indicate the fatigue strength decreases as a hyperbolic function of absolute temperature (2, 56).

Fatigue tests of plastics have been performed in axial load (46, 54, 57), flexure (11, 45, 49–52, 55), rotating beam (16a, 45, 50, 56), and torsion (45, 49, 50) machines. The effect of mean stress (3, 45, 49, 50) has been studied for a few plastics, as has the effect of speed of testing (3, 45, 50). The effect of shape of cross section, surface, and aging have been studied for fatigue of one plastic (3, 11). A method of estimating the fatigue strength from changes in thermal expansion has been applied to plastics (58).

Among the variables in fatigue conditions which have received little or no attention in tests of plastics are different combinations of principal stresses (57) (other than torsion), residual stresses, effect of anisotropy, effect of variations in composition, heat treatment and fabrication, and effect of size.

Repeated impact tests have been employed to obtain energy vs. blows diagrams (59, 60) from 1 to 10^6 blows. Calculations of stress produced by impact permitted correlation with fatigue tests (59).

CREEP IN TENSION AND COMPRESSION

Creep—usually an undesirable characteristic of materials—is a significant behavior of most plastics even at room temperature, so this subject has received considerable attention. Results of tension creep tests have been reported for filled (50, 51, 61–63), unfilled (7, 39, 63–70), and laminated (2, 19, 71–77) plastics at room temperature, and for molding materials (62, 63) and laminates at other temperatures (19, 56, 75, 77). Compression creep tests (70) and creep recovery (61, 62, 64, 71, 77) upon removal of load have also been reported.

Several methods of correlating creep data and representing them by mathematical expressions have been proposed. These include empirical equations (61, 70, 78), relations based on mechanical models consisting of different combinations of springs and dashpots (79, 80), relations based on the theory of rate processes and activation energy (75, 77, 83), and combinations of model and rate process theory (84–86). In all work of this sort, the utility of the results depend upon the accuracy and care with which the experimental work has been performed, and upon the precision with which the constants in the mathematical expressions can be determined from the test data. Also a point which deserves more attention than it receives has been described by someone as follows: The value of a theory is equal to the logarithm of the ratio of the number of facts it predicts to the number of undetermined constants in the equation.

Precise creep test work is difficult in any material and especially so in plastics because of the extreme sensitivity to small changes in temperature and relative humidity. The student of the literature will discern that some of the available data suffer from a lack of attention to details of testing procedure. A recommended practice for creep and relaxation testing of plastics (87) recently published may help to solve this problem.

While the use of mechanical models based on combinations of springs and dashpots is very useful as a tool for studying viscoelastic behavior, it is necessary for continued progress in the prediction of mechanical behavior of plastics to obtain a more fundamental understanding of the dynamics and kinematics of polymer molecules in their several levels of aggregation (88–90).

The Boltzmann superposition principle has been suggested to explain stress recovery and other memory effects in plastics (65). The fact that the per cent increase in strain during creep from one time to another time is independent of stress has been observed and compared with theory (2).

STRESS RELAXATION

A few tests of plastics under stress relaxation at constant strain (91–98) have been reported and interpreted in terms of spring-dashpot models (92, 95), and the theory of rate processes. Possible explanations of the mechanism of stress relaxation of polymers have been advanced (94). While the prediction of stress relaxation from creep test data has been the subject of considerable study for metals, no study of this difficult problem for plastics has come to the attention of the author.

CREEP IN BENDING AND TORSION

Creep tests of beams in bending (68, 70, 74, 76, 99) and bars in torsion (68, 70, 73, 74, 76, 100) have been reported for several plastics. The problem of prediction of deflections and stresses in beams during creep from data on creep in tension has been studied with varying degrees of success for both metals and plastics. Methods in which the creep time relation has been represented as

linear (for plastics) (68, 70, 76) have not been very fruitful. Results obtained more recently (101, 102) by use of equations which describe the tension creep curve more accurately have been more successful.

Results of one of the latter studies indicate that under certain conditions the stress distribution in a beam does not change during creep (102).

The problem of creep under combined principal stresses remains to be solved for plastics. The only data available are for torsion (indicated previously).

RELATION BETWEEN STATIC TESTS AND CREEP TESTS

The concept of a mechanical equation of state has been employed in deriving a stress-strain equation (103, 104) from an equation for creep based on the theory of rate processes. Comparison with test results shows good agreement. A graphical procedure of computing creep-time relations from tension test data has been applied to creep of methacrylate (105). The problem of relating static tests and creep tests is of considerable interest both in metals and plastics. It is hoped that a method will be devised which can overcome the limitation imposed by the mechanical equation of state—that the structure of the material must not change during the deformation.

RESIDUAL STRESSES, CRAZING, AND FRACTURE

The effect of residual stresses in plastics has often been observed and means of reducing these stresses discussed. The theory and the measurement of residual stresses for plastics have been considered by some investigators (106–108), and much more remains to be done in this important field.

Crazing of certain plastics is a serious problem and hence has been the subject of several investigations (109–114). Crazing of linear polymers has been described (110) as a mechanical separation of polymer chains or groups of chains under the action of tensile stress, and starts in a region where the polymer chains are oriented at right angles to the tensile stress.

The mechanism of fracture of plastics (115–117) has been described both from theory and experiment.

CONTACT FRICTION

Results of friction studies are available (118, 119) for several plastics.

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Communications

Concerning AMR 5, Rev. 3271 (November 1952): R. M. Goody, A statistical model for water-vapour absorption.

Article was incorrectly abstracted. For the corrected summary, see Rev. 683 in this issue.

Concerning AMR 5, Rev. 1082 (April 1952): G. Colonnetti, Elastoplastic equilibrium during passage of time.

Author's proof of theorem quoted contains statement (page 646, lines 6–7) that variations of plastic deformations are proportional to initial stresses. If this is taken to mean that each component of strain is proportional to corresponding component of stress, it contradicts basic assumptions of theory, and proof of theorem fails. If it is taken to mean merely that multiplying all components of stress by the same factor will multiply all components of strain by the same factor, theorem follows from the basic assumptions. However, basic assumption that all components of strain decay at some rate, is equivalent to taking the plastic Poisson ratio equal to the elastic, instead of the value $\frac{1}{2}$ required by experiment. F. R. N. Nabarro, England

Theoretical and Experimental Methods

(See also Revs. 378, 382, 400, 423, 450, 497, 519, 525, 531, 547, 551, 558, 559, 564, 566, 575)

324. Tetervin, N., A method for finding a least-squares polynomial that passes through a specified point with specified derivatives, *NACA TN* 2774, 11 pp., Sept. 1952.

A method is presented for finding an mth-degree polynomial that passes through a specified point with $(m - j)$ specified derivatives $(1 \leqq j \leqq m)$ and is a least-squares polynomial for other points spaced at unequal intervals of the independent variable. From author's summary

325. Kaplan, E. L., Numerical integration near a singularity, *J. Math. Phys.* **31**, 1, 1–28, Apr. 1952.

Paper gives tables to facilitate integration of the functions $x^n A(x)$, $n = \pm 1/2$ and $x^m[A(x) \log x + B(x)]$, $m = 0, 1$ in the vicinity of the singularity. Range of integration extends to a distance of twenty units from the origin. A number of auxiliary tables are also given. Y. Luke, USA

326. Ludwig, R., Graphic integration method of systems of differential equations and differential equations of the n-th order (in German), *ZAMM* **31**, 7, 201–208, July 1951.

Paper completes a series of three in which author has developed the application of Meissner line graphs to the solution of differential equations. The basic method is contained in the first two papers [AMR **5**, Rev. 322], and the paper at hand generalizes the method to include systems of linear differential equations and also differential equations of higher order. The estimation of error is again discussed.

The method is applied to the solution of the second-order differential equation of the catenary, and of the undamped nonharmonic oscillation of a pendulum.

J. R. Bruggeman, USA

327. Hunter, G. T., Modern computing machines, *J. Franklin Inst.* **253**, 6, 567–583, June 1952.

A qualitative, semi-technical description of the history, philosophy, and current practice of large-scale, digital computing machines, suitable as an elementary introduction to the subject for engineers not specializing in computer techniques.

G. W. Swenson, Jr., USA

328. Schneider, P. J., The Prandtl membrane analogy for temperature fields with permanent heat sources or sinks, *J. aero. Sci.* **19**, 9, 644–645, Sept. 1952.

Analogy mentioned in the title is shown to be similar to familiar membrane analogy for torsion. Differential equation for temperature in a region of constant thermal conductivity generating or absorbing heat is same as equation for deflection of a membrane stretched over the same region and subjected to a constant pressure difference. The temperature at any point is proportional to the corresponding deflection of the membrane. Boundary conditions are mentioned briefly. Experimental evidence is mentioned but references are not cited. W. B. Stiles, USA

329. Tippett, L. H. C., Technological applications of statistics, New York, John Wiley & Sons; London, Williams & Norgate, 1950, ix + 189 pp. $3.50.

This book is derived from a series of lectures given to a mixed audience, including some with no background or training in statistics, at M.I.T. in 1948. Tippett, English statistician and author of the well-known "Tippett's random numbers," steps down from the mathematics journals to discuss in simple terms the practical uses of statistics in industry.

No mathematics beyond algebra is used, and very little theory is developed. However, most of the basic concepts pertinent to quality control are presented, including the statistical distribution, the control chart, single, double, and sequential sampling, the analysis of variance, randomization, and the use of randomized blocks. A large number of numerical examples are given, and a short bibliography is included.

It should be pointed out that the absence of theory leaves no logical basis for some of the steps in the treatment, and occasionally the reader is left suspended. The book should not be considered as sufficient to enable one to perform actual quality control. Nevertheless, it gives a good intuitive comprehension of most

basic concepts, and going through the numerical examples tends to make these ideas clear. C. R. Gates, USA

330. Korn, G. A., and Korn, Theresa M., Electronic analog computers, New York, McGraw-Hill Book Co., 1952, xv + 378 pp. $7.

It has become stylish since the end of World War II to expend a lot of time, money, and effort on large-scale computers. This has been accomplished by much publicity in magazines, newspapers, and in lectures. Extravagant claims have been the rule, and expressions such as "a machine to replace the human brain" have been commonplace. When such a movement gets under way, it is important that a survey of accomplishments be made from time to time so that the scientific public can evaluate the actual situation.

Two major types of computers have appeared during this postwar period: digital and analog. Whereas the first type has motivated most of the publicity and has clothed itself with an air of glamor, the second has become the unglamorous workhorse of the trade. Several lines of dependable computers, mostly developed under military contracts, are now commercially available, and many computing centers exist which are devoted to the solution of scientific and engineering problems. Authors have made a significant contribution in surveying the analog devices available and the theory upon which they operate. The analog-computing field is a rapidly expanding one, with new developments appearing frequently. Hence the book must be viewed as a status report as of the date it was presented to the publisher, say late 1951.

The modern analog computer is a natural outgrowth of the mechanical differential analyzer as described by Bush and Caldwell, who established the computing philosophy of such devices, and the rapid development of feedback principles during the war years. The end result has been the development of quite versatile analog computers which are relatively cheap and largely electronic. These devices solve sets of simultaneous ordinary differential equations which may be either linear or nonlinear. These computers are not efficient in solving either partial differential equations or statistical problems.

The book naturally divides itself into two major parts. The first three chapters constitute the first part and cover the philosophy of analog computing, operating procedures, and typical problems. The second part, consisting of five chapters, is devoted to the technical problem of building computing components and their integration into a general purpose computer. The first part is straightforward, for one of the beauties of analog computing is that the basic principles are essentially simple.

Authors have done an excellent job in discussing devices and systems that have appeared to date. A reasonable division has been made between slow and repetitive computers and their good and bad points accurately compared. They have pointed out the general accuracy, dependability, and flexibility of operational amplifiers, but have not glossed over the relative unsatisfactory performances of multipliers and function generators. In short, the book is a must for anyone who contemplates the purchase or the development of an analog computer. It clearly points out the best techniques that have appeared and can thus save a designer from making many false starts. Numerous references are given so that the interested reader can pursue any special topic more thoroughly.

To a reader interested in analog computing in the broad sense, the lack of any reference to network computers may come as a disappointment. Authors have chosen to limit their book to d-c analog computers, and in this they are perhaps wise, for the philosophy, operation, and design of network computers are so different that their inclusion would make the book too large. H. M. Trent, USA

331. Ling, C. B., Tables of values of the integrals, ${}_0\int^\infty (x^m/\sinh^p x)dx$ **and** ${}_0\int^\infty (x^m \cosh^p x)dx$, *J. Math. Phys.* **31,** 1, 58–62, Apr. 1952.

Paper gives values of $I(m, p) = A\ {}_0\int^\infty x^m dx/\sinh^p x$, and $J(m, p) = A\ {}_0\int^\infty x^m\, dx/\cosh^p x$ and also the reciprocal of the auxiliary function $A = p^{m+1}/2^p(m!)$. The integrals are given mostly to 5*d* for all admissible pairs of p and m, $p = 1\,(1)\,8$, $m = 0\,(1)\,15$. The auxiliary function is given exactly or to 6*s* for same range. C. W. Nelson [AMR **5,** Rev. 67] has tabulated an integral simply related to $I(m, p)$ to 12 *d* for $m = 1\,(1)\,40$. Entries common to both tables are in perfect agreement. Y. Luke, USA

332. Minorsky, N., On systems with retarded action (in French), *C. R. Acad. Sci. Paris* **234,** 20, 1945–1947, May 1952.

Author considers the differential-difference equation $\ddot{x} + a\dot{x} + x_h + \epsilon x_h^3 = 0$, where $x(t)$ is the dependent variable and $x_h = x(t - h)$, where h is a constant. a, ϵ, and h are small parameters of the same order. By means of substitutions associated with the polar coordinate system, the preceding equation is transformed into a system of two differential equations. Solutions in power series of the form $\Sigma_{i=0}^{\infty}\epsilon^i X_i(t)$ are sought. The approximation of order one leads to a pair of differential equations. To these, the so-called stroboscopic method, explained more fully by the author in a previous note [see AMR **5,** Rev. 611], is applied to discuss conditions under which the stationary amplitude is stable or unstable. E. J. Scott, USA

333. Hildebrand, F. B., On the convergence of numerical solutions of the heat-flow equation, *J. Math. Phys.* **31,** 1, 35–41, Apr. 1952.

Let $u(x, t)$ be the solution of the partial differential equation $u_{xx} = u_t$ $(0 < x < 1,\ t > 0)$ with boundary conditions $u(0, t) = u(1, t) = 0$ $(t > 0)$, $u(x, 0) = f(x)$, and let $v_{\mu,\nu}{}^{(M)}$ $(= v(\mu\Delta x, \nu\Delta t))$ be the solution of the finite difference equation $r(v_{\mu+1,\nu} - 2v_{\mu\nu} + v_{\mu-1,\nu}) = v_{\mu,\nu+1} - v_{\mu\nu}$ with boundary conditions $v_{0\nu} = v_{M\nu} = 0$, $v_{\mu 0} = f(\mu/M)$ $(\Delta x = 1/M,\ \Delta t = r/M^2)$. It is shown that if $f(x)$ is continuous in (0, 1) except for a finite number of finite jumps and is of bounded variation in (0, 1), and if $0 < r < \frac{1}{2}$, that $\lim_{M\to\infty} v^{(M)} = u(x, t)$. Same is proved to be true for $r = \frac{1}{2}$, if $f(x)$ can be expressed as an absolutely convergent Fourier series for $0 \leqslant x \leqslant 1$, but it is surmised that it might be true for $r = \frac{1}{2}$ for a wider class of functions f. D. ter Haar, Scotland

334. Malkin, I. G., On the construction of Lyapunov functions for systems of linear equations (in Russian), *Prikl. Mat. Mekh.* **16,** 2, 239–242, Mar./Apr. 1952.

Let $\dot{x}_s = p_{s1}x_1 + \ldots + p_{sn}x_n$ be a system of differential equations, p_{sj} being continuous bounded functions of t in $(0, \infty)$. Let $x_{sj}{}^0(t, t_0)$ be a fundamental system of solutions, $x_{sj}{}^0(t_0, t_0) = \delta_{sj}$ and assume $|x_{sj}{}^0(t, t_0)| < Me^{-\alpha(t-t_0)}$ for $t \geqq t_0 \geqq 0$, M, α positive constants. Let $W(t, x_1, \ldots, x_n)$ be any positive definite form of degree m in $x_1, \ldots, x_n$ whose coefficients are continuous bounded functions of t. Then

$$V = {}_t\int^\infty W(\tau, y_1, \ldots, y_n)d\tau$$

where $y_s = x_{s1}{}^0(\tau, t)x_1 + \ldots + x_{sn}{}^0(\tau, t)x_n$, is a positive definite function of Lyapunov, which is a form of degree m in $x_1, \ldots, x_n$ with bounded coefficients, satisfying the equation $dV/dt = -W$. This theorem generalizes previous results by Lyapunov and Malkin.

Courtesy of Mathematical Reviews J. L. Massera, Uruguay

335. **Hyman, M. A., Non-iterative numerical solution of boundary-value problems,** *Appl. sci. Res.* (*B*) **2, 5,** 325–351, 1952.

A method is presented for the numerical solution of boundary-value problems. The method is applicable to arbitrary regions in any number of dimensions. The technique of solution is non-iterative and appears well adapted to use with high-speed computing machines.

From author's summary by M. Stippes, USA

336. **Bundscherer, N., On the conformal transformation of certain rectangular octagons** (in German), *ZAMM* **31,** 11/12, 370–387, Nov./Dec. 1951.

By superposition of two notched rectangles that can be represented by relatively simple functions, author gives the conformal representation of certain rectangular octagons. The parameter values of the integral that gives the representation are computed from the sides of the octagon. By continued reflection of the octagons (especially of degenerate ones), a great number of representable regions are generated.

From author's summary by J. DeYoung, USA

337. **McIlroy, M. S., Nonlinear electrical analogy for pipe networks,** *Proc. Amer. Soc. civ. Engrs.* **78,** Separ. no. 139, 11 pp., July 1952.

Paper is a résumé of a more complete paper describing network analogy [*J. A.W.W.A.* **42,** p. 347, 1950]. Paper gives outline of analogy between head loss and voltage and between discharge and current. Construction of analyzer is described briefly. New addition over previous analogies is a resistor simulating nonlinear head loss. Either Hazen-Williams or Darcy law may be used to define head loss. Example of accuracy obtainable with analyzer is given. Reviewer believes engineers would find original paper of more value. W. D. Baines, Canada

338. **Abramowitz, M., Coulomb wave functions expressed in terms of Bessel-Clifford and Bessel functions,** *J. Math. Phys.* 29, 4, 303–308, Jan. 1951.

The regular solution of the Coulomb wave equation

$$\frac{d^2y}{d\rho^2} + \left[1 - \frac{2\eta}{\rho} - \frac{L(L+1)}{\rho^2}\right] y = 0 \qquad [1]$$

is to be tabulated for $L = 0(1)5, 10, 11, 20, 21$; $\rho = 0(.2)5$; $\eta = -5(1)5$. Author gives expressions for the regular solution which will be useful outside the range of the tables. The regular solution $y = F_L(\eta, \rho)$ of [1] is normalized in such a manner that as $\rho \to \infty$

$$F_L(\eta, \rho) \sim \sin\left\{\rho - \eta \ln 2\rho - \frac{L\pi}{2} + \arg \Gamma(L + 1 + i\eta)\right\}$$

The power-series expansion of $F_L(\eta, \rho)$ is

$$F_L(\eta, \rho) = C_L(\eta)\rho^{L+1}\phi_L(\eta, \rho)$$

where

$$C_L = \left\{\frac{2\pi\eta}{\exp(2\pi\eta) - 1}\right\}^{1/2} \frac{2^L}{\Gamma(2L+2)} \left|\Gamma(L + 1 + i\eta)\right|$$

The function $\phi_L(\eta, \rho) = u$ satisfies the differential equation

$$\rho u'' + (2L + 2)u' + (\rho - 2\eta)u = 0 \qquad \text{with } u = 1 \text{ for } \rho = 0$$

In the first, an expansion of u is given in terms of the modified Bessel-Clifford function $E_n(t) = t^{-n/2}I_n(2\sqrt{t})$ when η is large.

$$\phi_L(\eta, \rho) = k(\eta)\left[E_{2L+1}(2\eta\rho) + \sum_{s=1}^{\infty} a_s(\eta)E_{2L-s}(2\eta\rho)\right]$$

where $k^{-1}(\eta) = 1/(2L + 1)! + \sum_{s=1}^{L} a_s(\eta)/(2L - s)!$ and the coefficients $a_s(\eta)$ are given by recurrence relations. In the second place, $\phi_L(\eta, \rho)$ is expanded in terms of the Bessel functions, which expansion is useful when η is small and ρ is large

$$\phi_L(\eta, \rho) = \sum_{n=0}^{\infty} b_n(\eta)J_n(\rho), \quad b_0 = 1$$

The coefficients $b_n(\eta)$ are given by recurrence relations. The last expansion may also be obtained with the aid of the Laplace transform.

Courtesy of Mathematical Reviews S. C. van Veen, Holland

339. **Pleijel, Å., On Green's functions for elastic plates with clamped, supported and free edges,** Proc. Symp. Spectral Theory Differential Problems, Oklahoma Agric. Mech. College, Stillwater, Okla., pp. 413–437, 1951. $3.

In his paper on eigenvalue distributions, H. Weyl [*Rend. Circ. Mat. Palermo* **39,** 1–50, 1915] considered various three-dimensional differential problems, and in a series of lemmas he derived estimates for the Green's functions connected with them. For example, for the Green's function $G(p, q) = (4\pi r_{pq})^{-1} - \gamma(p, q)$, for the Dirichlet problem for Laplace's equation for the three-dimensional region V, Weyl showed that the "regular part" γ satisfies

$$\gamma(p, q) = 0(1/R(p, q))$$

where R denotes the "light distance" between the points p and q of V after one reflection at the boundary S of V, i.e., $R(p, q) = \min_{s \in S}(r_{ps} + r_{qs})$. In the present paper, author considers analogous questions concerning Green's functions for three boundary-value problems for the two-dimensional biharmonic equation $\Delta\Delta u = 0$ in a plane domain V with a smooth boundary, with boundary conditions corresponding to those of a clamped plate, a simply supported plate, and a plate with free edges. The Green's functions for these three problems are constructed with the help of integral equations, after modifying the boundary conditions slightly in order to be able to apply the Fredholm theory. It is shown that if $\gamma(p, q)$ denotes the regular part of Green's function for any of these problems, then

$$\begin{aligned} \gamma(p, q) &= O(1) \\ D\gamma(p, q) &= O(1) \\ D^2\gamma(p, q) &= O(|\log R(p, q)|) \\ D^{k+2}\gamma(p, q) &= O(R^{-k}(p, q)), \; k > 0 \end{aligned}$$

where $D = \partial/\partial x$ or $\partial/\partial y$, and $R(p, q)$ is the light distance of the points p and q of V from the boundary of V. It is also shown how to construct the requisite Green's functions by using Weyl's method.

Courtesy of Mathematical Reviews J. B. Diaz, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 326, 371, 448)

340. **Hirschhorn, J., The forces and pressure distribution in brake shoes,** *Engineering* **173,** 4509, p. 815, June 1952.

Proof that the pressure distribution on hinged shoes can be represented by a single circle. D. Mazkevich, USA

341. **Kuz'min, P. A., Supplement to V. A. Steklov's case of motion of a heavy rigid body around a fixed point** (in Russian), *Prikl. Mat. Mekh.* **16, 2,** 243–245, Mar./Apr. 1952.

Paper refers to a work of V. A. Steklov concerning the motion of a body relative to a fixed point on one of its central principal axes of inertia. Taking this axis as the x-axis, the position of the

body is determined by the cosines of the angles which Ox, Oy, Oz (fixed in the body) make, respectively, with the vertical axis Oz (fixed in space). The motion of the body examined by Steklov is possible for a wide class of bodies, because the principal moments of inertia A, B, C, and the coordinate x_c of the mass center, which are characteristic for similar kind of bodies, are essentially subjected only to one condition $A > 2c$, provided $B > A > C$. The author's supplement to this work consists in treating the problem in the case $A > B$, the mass center being on the axis corresponding to the greatest moment of inertia.

J. Beránek, Czechoslovakia

342. Harrison, M., Sykes, A. O., and Marcotte, P. G., The reciprocity calibration of piezoelectric accelerometers, *J. acoust. Soc. Amer.* **24,** 4, 384–389, July 1952.

See AMR **5,** Rev. 2764.

343. Taylor, J., Accelerometers for determining aircraft flight loads, *Engineering* **173,** 4498, 4499; 473–475, 506–507; Apr. 1952.

Aircraft subjected to gusts and maneuvers experience resulting accelerations of relatively small value. These values are masked by higher accelerations embodied in structural vibration if accelerometer is responsive to high frequencies. Paper describes accelerometer having relatively flat low-frequency response and marked attenuation at high frequencies.

Accelerometer includes main mass supported within case by damped spring. Small flywheel mounted to case is coupled to main mass by tape and roller mechanism in series with secondary spring, so that linear movement of main mass tends to rotate flywheel. Acceleration is indicated by angular displacement of flywheel with respect to case. One version of accelerometer has pointer on flywheel shaft and ratchet mechanism operated by pointer to count occurrences of acceleration.

Performance of accelerometer is compared with that of conventional damped, single-degree-of-freedom accelerometer. Amplitude response of flywheel instrument is somewhat greater at low frequencies, and substantially lower at high frequencies, i.e., cut-off is noticeably sharper. Change in time lag from that at zero frequency is approximately same for two instruments at low frequency, but greater for flywheel instrument at high frequency. Latter effect is unimportant because of low amplitude response.

Charles E. Crede, USA

344. Jarre, G., On the relative motion in continuous media (in Italian), *Atti Accad. Sci. Torino* **85,** 183–191, 1950–1951.

Author gives the relation between the local derivatives of the scalar and vector function calculated by two observers in relative motion. Assuming that the stationary observer (F) is attached to the set of axes (T), and the moving (M) to the set (τ), one obtains $(f_t)_M - (f_t)_F = \mathbf{U} \times \text{grad}\, f = \text{div}\, f\mathbf{U}$, where $f = f(\mathbf{r}, t)$, $\mathbf{U}$ is the transfer velocity of the point of measurement, and $\times$ the sign of scalar product. It follows that the total derivative as well as the difference of the local derivatives are invariants with respect to the chosen set of axes, whereas the locals themselves are not, on account of the "virtual derivatives" $\mathbf{W} \times \text{grad}\, f$, $\mathbf{V} \times \text{grad}\, f$, where $\mathbf{V} = \mathbf{W} + \mathbf{U}$.

For function $\mathbf{a} = \mathbf{a}(\mathbf{r}, t)$ one obtains $(\mathbf{a}_t)_M - (\mathbf{a}_t)_F = \text{grad}\, \mathbf{a} \times \mathbf{U} + \text{rot}\, \mathbf{a} \wedge \mathbf{U}$, where $\wedge$ is the sign of vector product. Therefore, we have $(\mathbf{U}_t)_F = -(-\mathbf{U}_t)_M$.

The derived relations are applied to the equation of continuity and the Navier-Stokes equation of viscous fluid. By means of the vectorial operator, one obtains the absolute (applying $\wedge$ to $\mathbf{V}$ in T), relative (applying $\wedge$ to $\mathbf{W}$ in τ), and transfer acceleration (applying $\wedge$ to $\mathbf{U}$ in T or τ).

D. Rašković, Yugoslavia

345. Shul'gin, M. F., On the theory of the Lagrange equations for nonconservative systems (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **83,** 3, 373–376, Mar. 1952.

This paper is a continuation of an earlier one by the author [AMR **5,** Rev. 1945], and establishes a theorem, analogous to the classical theorem of Poisson, on integrals of Lagrangian equations for nonconservative systems. By the introduction of superfluous variables, the given Lagrangian system is replaced by an extended one. Given an integral of each system, the theorem provides a new integral of the original one. If the given integral of the original system is linear with respect to the velocities, the corresponding extended system can be reduced to the Lagrangian form with respect to the superfluous variables.

E. Leimanis, Canada

346. Starzhinskii, V. M., Sufficient conditions for stability of a mechanical system with one degree of freedom (in Russian), *Prikl. Mat. Mekh.* **16,** 3, 369–374, May/June 1952.

By considering the behavior of a suitable quadratic form $V(t) = ax^2 + 2bxy + cy^2$, where $\dot{x} = y$, $\dot{y} = -q(t)x - p(t)y$, a method first introduced by Lyapunov, author presents some sufficient conditions for the boundedness of the solutions of $\ddot{x} + p(t)\dot{x} + q(t)x = 0$. As an interesting application, he considers the case where $p(t) = a$, $q(t) = 1 + r \cos 2t/k$, $0 < r < 1$.

R. Bellman, USA

347. Chetaev, N. G., On unstable equilibrium in certain cases when the force function is not maximum (in Russian), *Prikl. Mat. Mekh.* **16,** 1, 89–93, Jan./Feb. 1952.

Certain criteria of instability based on the idea of Lyapunov's functions, which were previously proved by the author [N. G. Chetaev, "Stability of movement," Gostekhizdat, Moscow, 1946], are here applied to establish the instability of equilibrium points of dynamical systems in several cases when the force function is not maximum.

Courtesy of Mathematical Reviews J. L. Massera, Uruguay

348. Rubbert, F. K., Forced pendulum oscillations of infinite amplitude (in German), *Z. Phys.* **127,** 72–84, 1950.

In order to explain the differences in the qualitative behavior of the solutions of Duffing's equation $\ddot{x} + n^2x = bx^3 + a \cos mt$, author applies a method similar to that used by Poincaré in perturbation problems. The initial conditions are taken to be $x(0) = \alpha$, α small, and $x(0) = 0$. The solution is expanded in a series in α after the substitution $\tau = nt/(1 + \lambda\alpha^2)^{1/2}$. Only two terms are considered: $x = \alpha f(\tau) + \alpha^3 g(\tau)$, and higher terms in α are neglected. Two linear differential equations are obtained for the functions f and g. The parameter λ is so determined that the solutions for f and g remain bounded in time, λ appears as a root of a polynomial of third degree. The behavior of the resulting approximate solution is discussed at length. No convergence properties of full expansion or estimates of error are considered.

Courtesy of Mathematical Reviews F. Bohnenblust, USA

Gyroscopics, Governors, Servos

(See also Revs. 363, 527, 597)

349. Janssen, J. M. L., Analysis of pneumatic controllers, "Automatic and manual control," New York, Academic Press, 189–200, 1952. $10.

The frequency-response method of defining the characteristics of a controller is indicated to be preferable to the specification of integral and derivative action times. The reason is the ease with which the frequency diagram—especially when it is approximated

by straight lines on log-log paper—incorporates any number of separate units in the controller. In addition, the break points in such a diagram can be readily determined for a controller; in a typical pneumatic controller used as an illustration, they correspond directly to the dial settings of the controller. A discussion is presented of the nonlinear effects introduced by output pressure and the variation of the resistance of restrictors with differential pressure. Herbert K. Weiss, USA

350. **Westcott, J. H., The development of relationships concerning the frequency band width and the mean square error of servo systems from properties of gain-frequency characteristics,** "Automatic and manual control," New York, Academic Press, 45–60, 1952. $10.

Paper concerns the problem of obtaining the optimum response of a position control servomechanism to a step input, and the problem of minimizing the mean square error in response to a specified input signal whose frequency spectrum is known. Author demonstrates, first, that a satisfactorily stable response to a step disturbance will be obtained when the amplitude response has a constant value of utility up to some cut-off frequency above which the phase has its limiting value. The limiting value of phase is determined by the order of the open-loop transfer function. The shortest possible transient-rise time will then be obtained by making this cut-off frequency as high as possible. Author next demonstrates that the magnitude of the mean square error of a servomechanism depends upon the band width over which the amplitude of the error function is constant.
S. Z. Dushkes, USA

351. **Layton, J. M., Some aspects of the problem of optimizing the performance of servo systems incorporating rotary generators,** "Automatic and manual control," New York, Academic Press, 65–76, 1952. $10.

Paper considers problem of improving performance of servo systems, assuming linearity, freedom from noise, and a signal frequency band well below natural frequencies of system. In particular, criteria developed apply to a cascaded sequence of dynamo-electric generators, without local feedback. Criteria enable designer to determine optimum relative magnitudes of time constants in sequence and optimum number of stages for a specified power amplification.

Essentially, method maximizes open-loop gain, while avoiding instability by holding phase or gain margin constant, by varying number and magnitude of time constants in a cascaded sequence. Author's results indicate that amplification per stage should be small and, in general, stages should have equal time constants.

Reviewer believes paper to be a useful contribution to design of electrical power-amplifying stages. W. A. Wolfe, Canada

352. **Kusters, N. L., and Moore, W. J. M., A generalization of the frequency response method for the study of feed-back control systems,** "Automatic and manual control," New York, Academic Press, 105–119, 1952. $10.

Authors develop a method for determining the degree of stability of a servomechanism, of which the transient response is known. The complex input frequency S is represented in polar coordinates ($u = |S|$, $\alpha = \sin^{-1}\zeta$, ζ = "damping factor"). The response amplitudes are plotted for different values of ζ in a decibel scale vs. the logarithm of the frequency. Changes of the gain constant K and of the unit of the frequency are equivalent to shift of the abscissa axis and of the ordinate axis, respectively. The method may be used to determine the gain of a servomechanism if the damping factor is predetermined.

Formulas are derived which give the coefficients of real and complex unique roots as functions of the slope of the response curve and of the Laplace transform of the input. The method is illustrated on four examples, and it is shown how it may be used for a study of frequency-response diagrams in general.
G. W. Braun, USA

Vibrations, Balancing

(See also Revs. 332, 337, 348, 428)

353. **Lembcke, H.-R., Bending and torsional vibrations of rods with arbitrary cross sections** (in German), *Ing.-Arch.* **20**, 2, 91–105, 1952.

Coupling between one bending vibration and one torsional vibration of rods with cross sections having one axis of symmetry ("dual coupling") has been treated previously. Author considers the case of arbitrary cross section, leading to two bending vibrations and one torsional vibration ("triple coupling"). Example: Angle iron with legs of unequal lengths. Assumptions: Rods are not twisted in unstressed state; distributions of masses and moments of inertia are continuous; linear theory of elastic deformations is applicable; no influence of shear and rotational inertia; no damping. First, the differential equations of the problem are set up as the Euler equations to Hamilton's principle, assuming sinusoidal functions of time. Result: Set of three ordinary differential equations, two of fourth order, one of second for the eigenfunctions in the three coordinates. Furthermore, the problem is treated by applying the Ritz method, using two-term approximations. The coordinate functions of the Ritz approximations are taken to be the eigenfunctions of the respective uncoupled (here called "free") vibrations. Result: A set of six linear algebraic equations for the Ritz parameters, the determinant of which is to vanish.

Next, the formulas are specialized for constant cross section. The differential equations for triple coupling are set up (tenth order with only even orders appearing). The frequency equation accordingly is of 5th degree in ω^2, the frequency squared, thus not allowing solutions in closed form. The special case of double coupling leads to differential equations of sixth order and a frequency equation of 3rd degree in ω^2. In an example, having double coupling (angle iron with legs of equal length), the results of both the differential equation method ("exact" solution) and the Ritz method ("approximate" solution) are given and compared. The natural frequencies agree well (errors of 0.030%, 0.074%, 0.72%, respectively, for the first three modes). From this, the conclusion is drawn that the errors for triple coupling will be of the same order of magnitude.

Finally, experimental results for the frequencies are given; they, too, check well with the calculated ones. Conclusions: The disturbance of the "free" (uncoupled) frequencies by the coupling is such that the free frequencies are "driven apart" by the coupling; the change being greater the closer the frequencies were originally (order of magnitude, up to 10%). Paper lacks in stating the notation clearly; author obviously expects the symbols used to be self-explanatory. K. Klotter, USA

354. **Melyakovetskiĭ, A. S., Integral equation of free vibrations of a curved bar** (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **85**, 3, 513–516, July 1952.

The free vibrations in bending of a thin rod originally in the shape of a plane curve of unchanging length are considered. The ends are elastically supported and the vibrations occur in its own plane. The formulation as an integral equation leads to an equation of Fredholm type with a positive definite symmetric kernel and the existence of a complete set of orthonormal functions

and corresponding real frequencies of vibration for the system.
E. Saibel, USA

355. Soroka, W. W., Equivalent dynamical systems for complex vibration problems, *Prod. Engng.* **23,** 7, 130–133, July 1952.

Influence coefficients are converted to spring stiffnesses of an equivalent single-string lumped-mass system.
From author's summary by A. C. Hagg, USA

356. Das Gupta, S. C., Transverse vibration of a wooden plate, *Bull. Calcutta math. Soc.* **43,** 4, 143–146, Dec. 1951.

Author analyzes free, transverse vibrations of a thin strip of orthotropic plate. He applies solution to a wooden plate; however, analysis has wider practical applications, particularly to engineering alloys whose isotropy has been destroyed during the manufacturing process (e.g., cold-rolled copper).

Author assumes that the state of stress is plane, and that the plate is cut parallel to a plane of elastic symmetry. Problem is solved by combining Hooke's law for orthotropic materials with classical analysis of vibrations of an elastic body. Boundary conditions are that the upper and lower plate surfaces are free from stress. Characteristic equation is a cubic, but yields only two significant natural frequencies. Solution agrees with Timoshenko's analysis of the same problem for isotropic material [*Phil. Mag.* (6) **43,** 125–130, Jan. 1922].
M. C. Junger, USA

357. Myklestad, N. O., The concept of complex damping, *J. appl. Mech.* **19,** 3, 284–286, Sept. 1952.

Author shows that, if the hysteresis loop for a material has a particular shape, the damping can be considered adequately by multiplying the modulus of elasticity of the material by the complex number e^{2bi}, where $2b$ is called the complex damping factor. For small values of b, it is shown that both for free and forced vibrations of a simple spring-mass system the motion in the case of complex damping is the same as in the case of viscous damping, with $b = c/c_r$, except that, in the steady-state case, the phase angles are slightly different. Also, it is shown how complex damping may be applied to cases of forced vibrations of uniform rods and beams. The greatest advantage of using complex damping, however, is in numerical calculations of forced vibrations of engine crankshafts, airplane wings, and other types of structures; and for such calculations it already has been used extensively.
From author's summary by Tsuneji Rikitake, Japan

358. Bogdanoff, J. L., Whirling of a bladed disc, *J. aero. Sci.* **19,** 8, 519–528, Aug. 1952.

Paper studies effect on the critical whirling speed of a massless cantilever shaft rotating and carrying a narrow disk at its end, when a number of flexible blades are attached to the rim of the disk. Method follows closely author's previous paper [AMR **1,** Rev. 15]. Author concludes that whirling takes place only if the blades are free to bend in the plane of disk or perpendicular to it, or else the precession speed and the rotating speed must bear a certain definite ratio. There is an obvious oversight in the statement that precession was possible at zero rotating speed.
L. S. Dzung, Switzerland

359. Roberson, R. E., Synthesis of a nonlinear dynamic vibration absorber, *J. Franklin Inst.* **254,** 3, 205–220, Sept. 1952.

Paper discusses the synthesis of a nonlinear spring characteristic which will permit satisfactory operation of an absorber over a wider range of frequencies than that permitted by a linear spring. The absorber is to be used on an undamped vibrating system having a single degree of freedom and subjected to a harmonic exciting force. The synthesis is confined to the choice of best parameters for a spring whose characteristics consist of the sum of a linear and a cubic term. Using the first term approximation by the Duffing method, optimum design parameters are obtained as functions of the excitation frequency which is to be expected in use. The synthesis is evaluated for a particular operating frequency, and the results are found to be in good agreement with those obtained by a more exact numerical process and with those obtained by an electronic differential analyzer. Results indicate that a nonlinear absorber spring would be more effective than a linear spring in that the slope of the resonance curves near the working frequency would be reduced. This would permit a greater frequency drift without amplification of the vibration.
Paul G. Jones, USA

360. Takahashi, T., and Okura, A., On a coupled vibration of propeller blades and crank shaft, *Japan Sci. Rev.* **2,** 1, 1–10, Apr. 1951.

An analysis is presented of the free vibrations of a system composed of a propeller coupled to an engine by a long shaft. In the analysis, the propeller blades are considered as a number of flat, uniform, elastic bars, the long shaft is regarded as a continuous body with distributed inertia and rigidity, and the engine is taken as a lumped moment of inertia. It is assumed that the propeller blades bend and that the shaft undergoes torsional oscillations during the motion. The dynamical equations for the coupled system are written, and the frequencies and modes for various ratios of the inertia parameters of the system are deduced.
L. A. Pipes, USA

361. Dubs, W., Recent investigations of steam turbine blade vibrations, *Escher Wyss News,* 23/24, 61–68, 1950/1951.

Author reviews certain analytical and experimental procedures which are used in the vibration investigations of turbine blades. Particular emphasis is placed on the problems associated with the low-pressure stages of condensing turbines in which the blades are of considerable length and low flexural rigidity. The effect of centrifugal force on the vibratory characteristics of such blades is stressed. Nodal patterns are shown for sample blades, and methods of measuring the damping are discussed.
R. H. Kemp, USA

362. Sponder, E., On the representation of the stability region in oscillation problems with the aid of the Hurwitz determinants, *NACA TM* 1348, 12 pp. Aug. 1952.

Translation of paper reviewed in AMR **4,** Rev. 1019.

363. Poggi, B., On stability criteria for small oscillations with applications to the regulation of hydroelectric plants (in Italian), *Energia elett.* **29,** 5, 286–297, May 1952.

Author discusses previously published methods of Routh, Nyquist, and others and applies them to a complete hydroelectric system, which is described by ten simultaneously linearized equations.
J. P. den Hartog, USA

364. Reckling, K. A., Stability of forced harmonic vibrations of straight I-beams in the frame of a structure (in German), *Ing.-Arch.* **20,** 3, 137–162, 1952.

A load-bearing system is presumed to be influenced by a static load and a pulsating force causing a stationary harmonic vibration. Under the assumption that the free vibration has already ceased, and neglecting the effect of rotatory inertia and damping, the stability of one of the beams belonging to the system is studied. Equations of equilibrium are set up for the beam, in-

cluding the time-dependent sectional forces at the boundaries (bending and torsional moment, axial and shearing force) as well as a time-dependent transversal load in resonance with the forced vibration of the system. A stability computation is carried out for the simple case of pulsating boundary moments of equal magnitude. Having developed the neighboring displacements of the beam (lateral and torsional displacement), an unlimited number of partial differential equations are obtained which may all be solved in succession. For the purpose of simplification, author introduces a probably new method comprising an expansion of the neighboring displacements of the beam due to a parameter which is small and independent of the amplitudes of loading. As a result, a number of ordinary differential equations with constant coefficients are obtained. After they are solved, the area of instability may be represented in diagrams. The method is demonstrated by numerical examples. A comparison is made between the results obtained and the values found by other authors.

Sven T. A. Ödman, Sweden

365. **Escande, L., Calculation of water oscillations in communicating basins** (in French), *Bull. Acad. Serbe Sci.* **8**, 2, 5–30, 1952.

Starting from the classical formula which defines the motion of the water in two cylindrical vertical storage tanks connected by a pipe with no loss of head, author shows, analytically, how it is possible to solve the case where the number of storage tanks is n, where the head losses are no longer negligible, and where the horizontal cross sections of the tanks are no longer constant.

In the case of three or more storage tanks, when one considers the head losses, the calculations, which are of a more complex order, are made by limit differences according to the progressive variations in time of the phenomena.

It would seem that the method suggested could be replaced by graphical processes similar to those described by Bouvard and Molbert [see AMR **5**, Revs. 159 and 3449].

Ph. Alexandre, France

366. **Kharkevich, A. A., Impulse analysis by means of resonators** (in Russian), *Zh. tekh. Fiz.* **21**, 8, 886–891, Aug. 1951.

The spectrum of an impulse is given by its Fourier transform. When a group of resonators, with mass m_k and frequency ω_k but without damping, is agitated by an impulse of finite duration, after extinction of the impulse, the amplitude of each resonator is $(1/\omega_k m_k)|F(\omega_k)|$. So the value of the function $|F(\omega)|$ can be measured for ω equal to the resonance frequency of each resonator.

When damping is present, the vibrations of the resonators are decaying, but at every moment after the impulse has ended, the ratios of the amplitudes of the resonators are equal to the ratios of the corresponding numbers $(1/m_k\omega_k)|F(\omega_k + j\,\alpha)|$, where α is the common damping constant of all resonators. So for the analysis of impulses, resonators with as little damping as possible must be used to get small distortion. W. H. Muller, Holland

367. **Haug, K., Torsional vibrations in reciprocating engines [Die Drehschwingungen in Kolbenmaschinen]**, Berlin, Springer-Verlag, 1952, v + 201 pp., 134 figs. DM 24.

This textbook is intended primarily for those with no previous specialized knowledge of the subject. It is divided into three parts: (1) General review of kinematics and dynamics as related to theory of torsional vibrations; (2) methods of substituting idealized for actual systems, and of calculating mass and moment distributions, natural frequencies, imposed frequencies, critical speeds, etc.; (3) consideration of design requirements from torsional vibration standpoint. Presentation is quite exhaustive, but clear, and illustrative numerical examples make practical application easy. Book contains little, if anything, original with author, but collects and presents other contributions and gives excellent and quite inclusive treatment of subject.

C. W. Smith, USA

368. **Klein, E., and Jenckel, E., Computation of free vibrations using the Maxwell theory** (in German), *Z. Naturforsch.* **7a**, 5, 305–313, May 1952.

The Maxwell model figure is very helpful in the study of the laws governing the behavior of high-molecular substances subjected to mechanical action. In this model, an elastoplastic body is assumed to be replaced by a mechanical device composed of an elastic spring whose fastening in the surrounding medium is regulated by a piston movable in the longitudinal direction of the spring. If a force acting in the same direction is applied to a mass fixed to the other end of the spring, the displacement of the point of application will be composed of an elastic deformation equal to the compression of the spring, and of a plastic deformation depending on the time of relaxation and equal to the movement of the piston in the direction of the force.

Applying the Maxwell fundamental equations, authors deduce the differential equations of free oscillations for the following systems: (a) An elastoplastic mechanical device; (b) two similar parallel-operating devices; (c) an elastoplastic and a purely elastic device; (d) two elastoplastic and a purely elastic device. The mechanical model may be replaced by an electrical model. The solutions of the differential equations are deduced and discussed. Formulas are also advanced for the logarithmic decrement of the first-mentioned three systems. After having shown that the free oscillation of the Maxwell model can be described in terms of complex modulus of elasticity, authors point out that the solutions obtained can also be applied to another problem, namely, rebound of a stiff body falling on an elastoplastic body.

Sven T. A. Ödman, Sweden

369. **Richards, G. R., Some electrical integrating circuits and their use in the measurement of low frequency vibration amplitudes,** *Aero. Res. Counc. Lond. Rep. Mem.* 2724, 18 pp., May 1948, published 1952.

The note investigates the possibility of making low-frequency vibration measurements by the use of electronic acceleration-measuring equipment in conjunction with electrical doubly integrating circuits. It is shown that, by this method, many of the disadvantages associated with the use of seismic displacement units can be obviated, particularly over the frequency range 2 to 40 cps. Three electrical integrating methods are discussed and the correct circuit conditions for the integration of periodic sinusoidal, rectangular, and triangular wave forms are derived.

From author's summary

370. **Grammel, G., On the stability of forced vibrations of elastic bodies with damping proportional to the velocity** (in German), *Ing.-Arch.* **20**, 3, 170–183, 1952.

Author derives equations of motion of conservative problem from variational principle, then adds damping terms. With a "character-preserving" tranformation which *should* read $\bar{u}_i(x_1, x_2, x_3, t) = e^{-\beta t/2\rho}U_i(x_1, x_2, x_3, t)$, $i = 1, 2, 3$, even-ordered derivatives are removed and transformed equations can be considered as Euler equations of an equivalent variational problem; accordingly, latter is open to direct methods of the variational calculus. Introduction of exterior forces which depend in periodic manner on time, identifies stability of the equivalent problem with that of the Mathieu equation. An example is worked out for three values of damping and compared to results with no damping.

R. M. Rosenberg, USA

Wave Motion, Impact

(See also Revs. 338, 536)

371. Müller, W., On the theory of the frictional impact of a ball on a plane wall and on another ball (in German), *Öst. Ing.-Arch.* **6**, 3, 196–208, May 1952.

Elementary mathematical solution of impact of a rolling billiard ball on another and on the cushion, based on the classical assumption that the relative tangential velocity of the points of contact after impact has the same sign as before impact (sliding) or vanishes (rolling). Consequently, in the first case, the angle of rebound is independent of the angular velocity of the ball before impact, contrary to the observed rebound of a billiard ball from the cushion. Author concludes thus (without proof) that, in this case, the conditions of rolling are satisfied, and he gives applications to the impact of three balls and to the energy loss. The results are discussed by means of exactly computed diagrams with regard to the conditions of sliding and rolling.

Reviewer believes that the oblique impact of rough bodies can hardly be treated with success by the elementary classical theory neglecting tangential and torsional displacements, as it follows from experiments of Howland and Dickson [*Phil. Mag.* (7), **2**, 1091–1098, 1926] and from a number of reviewer's papers [*C.R. Acad. Sci. Paris* **188**, 1929; *J. Ec. Polyt.* 2^e*s*, **28**, 1931; *Proc. seventh int. Congr. appl. Mech.*, 1949]. Recently [Z. Bažant, 70th Annivers. Vol., Prague, 1952] reviewer suggested an extension of the Hertz theory which, in his opinion, could be appropriate for resolving problems of impact of rough elastic bodies in accordance with experience. Z. Horák, Czechoslovakia

372. Homma, S., On boundary shear waves at an inner zone with continuously varying properties and related problems for surface waves, *Geophys. Mag., Tokyo* **23**, 1, 25–54, Dec. 1951.

Using Cartesian coordinates, author studies the existence and the characteristics of elastic waves (with displacements in the direction of z) progressing in the y-direction when density alone changes, and in the x-direction when both density and rigidity change. Density and rigidity are assumed to be symmetrical with respect to the yz-plane and to vary in such a way that they remain finite throughout the x-axis. Author treats two cases: In one, the medium extends from $x = -\infty$ to $x = +\infty$; in the other, from $x = x_0$ to $x = +\infty$ or $-\infty$. The entire paper concerns the mathematical solutions of the wave equation and the discussion of these solutions. The results show that the wave motion corresponding to the solution constructed vanishes when the variations of density and rigidity are not appreciable. Thus, the wave energy is concentrated in a zone where at least one of these properties has an appreciable rate of change in the x-direction. As is to be expected, the parameters characterizing the variations of density and rigidity appear in the characteristic equations relating the wave length to the wave celerity.

One peculiar feature of this paper is that the displacement has been considered independent of z. Chia-Shun Yih, USA

373. Liu, H. C., On the generation of ring waves on the surface of a liquid by a spherical periodical source situated below the surface (in German), *ZAMM* **32**, 7, 211–226, July 1952.

The source, of infinitesimal radius, is pulsating under the free surface of a frictionless fluid of great depth under gravity. The source strength is supposed so small that the linearized theory of surface waves is applicable. The problem is to calculate the velocity potential of the periodic forced motion. The solution must contain an arbitrary multiple of the regular standing-wave solution. For one definite value of this multiple, the solution satisfies Sommerfeld's radiation condition, i.e., at a distance from the source it represents waves traveling away from the source. (Reviewer's note: The solution can be derived as a limiting case from T. H. Havelock, *Phil. Mag.* (7), **8**, p. 575, 1929, and has been given explicitly by F. John [see AMR **4**, Rev. 2563], with an error in the sign of A.24 and later equations. In these papers, apparently unknown to the author, the case of finite depth is also treated.)

Author writes down formal solution, containing arbitrary constant, and next attempts to find asymptotic expansions for large and small distances. The mathematical discussion from here (p. 215) onward is on a rather low level. Reviewer remarks, e.g., that expressions 31, 32, 33, supposed to be valid when the distance r is large, involve series in positive powers of r. Author asserts, correctly but without proof, that these power series are negligible. (Correct argument by F. John, op. cit.) The surface elevation (39) is too large by a factor 2, which first appears in (30). The argument of section (e, β) is wrong. Reviewer noted that section (g) can be obtained more simply from (22) by expanding $J_0(\xi r)$ in a power series.

In fairness to the author, it should be stated that this work forms part of a Göttingen dissertation of 1945, evidently written under difficult conditions. F. Ursell, England

374. Biot, M. A., Propagation of elastic waves in a cylindrical bore containing a fluid, *J. appl. Phys.* **23**, 9, 997–1005, Sept. 1952.

Author analyzes the propagation of elastic waves in a circular bore through an infinite elastic solid in the two cases of an empty bore and a bore filled with a fluid. In the case of the empty bore, it is shown that the velocity of propagation of the surface wave increases from the Rayleigh-wave velocity to that of shear waves in the solid. In the case of the bore filled with fluid, it is shown that there is a wave which bears no resemblance to waves occurring independently in the two media, but which corresponds to water hammer in tubes. Results are shown in curve form for a wide variation of significant parameters. James W. Mar, USA

375. Kusukawa, K., On the shock wave in the elastic medium, *J. phys. Soc. Japan* **7**, 2, 200–203, Mar./Apr. 1952.

Paper discusses reflection by a plane rigid wall of shock wave set up by supersonic motion of wedge through elastic medium. Angles of incidence and reflection are tabulated for various shock strengths. To obtain rigorous shock relations, author extends his previous work [AMR **4**, Revs. 4089, 4090] by taking into account higher-order strain terms and thermodynamic conditions in the conservation laws. W. Freiberger, England

Elasticity Theory

(See also Revs. 331, 374, 392, 396, 403, 404, 415, 422, 432)

376. Filonenko-Boroditsch, M. M., Strength of materials. vol. I [Festigkeitslehre, Bd. I], Translation from Russian 3rd ed., 1949 (in German), Berlin, Verlag Technik, 1952, 444 pp.

This book on the strength of materials is the first of two volumes. Five Russians wrote the original, of which the present book is a translation into the German. It appears that the two volumes correspond roughly to the program presented by Timoshenko in his "Strength of materials," parts I and II.

The work is done in the best tradition of the old Russian schools and, by its systematic development, anticipates the more advanced works in the theories of elasticity and of plasticity. As would be expected, five of the total twelve chapters are devoted to the bending of beams or bars. One chapter is devoted to the buckling of bars, which is treated from the standpoint of

the fourth-order differential equation of equilibrium instead of the simple bending-moment equation so weakly presented in many American elementary texts. There are also treatments of stress specification, moments of inertia, statically indeterminate structures, and torsion. The multispan beam is studied in detail, as is also the well-known three-moment equation. Riveted and welded connections are considered only briefly.

A brave beginning is made upon the dynamics of structures in the last chapter. However, very little more than the derivation of the one-dimensional wave equation for strain and the determination of wave velocity are attempted. The chapter comes to an abrupt halt. It is hoped that in the second volume more attention is given to what the authors call dynamic problems.

About sixty problems are scattered throughout the book, and these, for the most part, are accompanied by solutions. The format is good and the print legible. There are many illustrative figures. W. H. Hoppmann, II, USA

377. Dantu, A new method for determination of stresses in plane elasticity (in French), *Ann. Ponts Chauss.* **122,** 4, 375–405, July/Aug. 1952.

Author reviews the analogy known to exist between plane problems in elasticity and Airy's differential equation with the flexure problems in unloaded thin plates and Lagrange's differential equation. By this correspondence between the stresses in plane slice and the curvatures and torsion of the deformed plate, when the latter has the proper boundary deformations, author utilized his optical method to determine these curvatures as direct measures of the stresses in the analogous plane slice. The method is applied to a problem of a square slice compressed by two equal opposite loads applied at the center of the opposite edge, and the results are compared with those contained by photoelastic methods. D. L. Holl, USA

378. Tiffen, R., Boundary-value problems of the elastic half-plane, *Quart. J. Mech. appl. Math.* **5,** part 3, 344–351, Sept. 1952.

Combinations of complex potential and Fourier integral methods are employed to solve problems of generalized plane stress of semi-infinite plates with one straight boundary. The method may be used to solve problems involving boundary stresses or displacements which are not expressible as Fourier integrals.

The investigations are confined to elastic material in equilibrium, subjected neither to body forces nor body couples, and in a state of generalized plane stress. C. B. Matthews, USA

379. Donato, L. F., Course in the science of construction. Part I. Elements of the theory of elasticity and strength of materials [Lezioni di scienza delle costruzioni. Parte prima: Elementi di teoria dell'elasticita; resistenza dei materiali], 2nd ed. (in Italian), Pisa, Colombo Cursi, 1949, ix + 282 pp. Lire 2200.

This book is the first in a series of four, dealing with the general subject of building construction. The second volume includes structural analysis; the third, details of metallic frames; and the fourth, elements of reinforced-concrete properties and techniques. The author is a professor at the University of Pisa, Italy, and this series of books is intended to be used as a text by the students.

In the first volume, after developing the fundamentals of the theory of elasticity, author deals with some problems in bending and torsion. In the two concluding chapters of this volume, the mechanical properties of some engineering materials are explained, a sketchy analysis of fatigue and theories of failure are given.

A. J. Durelli, USA

380. Donato, L. F., Course in the science of construction. Part II. Theory of beams and structural analysis. [Lezioni di scienza delle costruzioni. Parte seconda: Teoria delle travi; calcolo dei sistemi elastici], 2nd ed. (in Italian), Pisa, Colombo Cursi, 1950, vi + 284 pp. Lire 3000.

This is the second volume of the series mentioned in the previous review. In this volume, author deals first with the graphical and mathematical methods of analyzing beams of rectilineal and curvilineal axes. He introduces the principle of virtual work in the next section, gives some examples of analyses of simple structures, and explains influence lines. The last chapter deals with elements of elastic instability. A. J. Durelli, USA

381. Seth, B. R., Finite elastic-plastic torsion, *J. Math. Phys.* **31,** 1, 84–90, Apr. 1952.

With regard to a previously given solution for the finite torsion problem of circular elastic cylinder, author shows that the finite elastic-plastic torsion problem of a circular cylinder can also be treated, if the state of strain is referred to coordinates which are fixed in the strained body. The condition of continuity for the radial stress component can be satisfied only for the flow theory and not for the deformation theory.

H. Neuber, Germany

382. Brousse, P., foreword by Poncin, H., Study of partial differential equations encountered in the theory of torsion phenomena (in French), *Publ. sci. tech. Min. Air, Paris,* no. 257, 76 pp., 1952.

The Saint Venant-Michell theory of torsion of bars [A. E. H. Love, "Math. theory of elasticity," pp. 325–326, 1934] is extended to the case of an infinitely long circular cylinder containing a notch which is symmetric with respect to axis of rotation, but of arbitrary shape. The region of space studied is the portion of plane contained between the axis of rotation and two infinitely long straight line segments which are equidistant from the axis of rotation and connected at their end points by a finite continuous curve of arbitrary shape. The particular case in which the connecting curve is a semicircle is studied in considerable detail. Conformal representation of the plane section is utilized in obtaining solutions. There is brief discussion of solutions by series, analogy, experimental stress determination, and numerical method. A study is also given of existence, uniqueness, and principal properties of solutions. There is presented a derivation of stresses with special emphasis of stresses on the surface. Stress conditions at the intersections of the notch surface and the circular cylindrical portions receive careful treatment. Few numerical results are given.

Reviewer considers that this paper will be of particular interest to those concerned with mathematical studies of torsion. The hope is that the results will reach the level of application in technology. W. H. Hoppmann, II, USA

383. Sneddon, I. N., The stress produced by a pulse of pressure moving along the surface of a semi-infinite solid, *R. C. Circ. Mat. Palermo* (2) **1,** 1, 57–62, Jan./Apr. 1952.

Author solves a two-dimensional problem of a semi-infinite solid acted upon by a pulse of pressure moving with uniform velocity along the boundary $y = 0$.

Three examples are solved with various boundary conditions. In the first, only normal pressure is acting; the tangential is assumed to be zero. In the second, only the tangential pressure is applied while the normal pressure is assumed to be zero; and in the third, both pressures—the normal and the tangential—are acting simultaneously, and calculation is made by superposition. In solution of the problems, two conjugate functions are found

such that they satisfy the two-dimensional equations of equilibrium and the wave equations. These functions serve to determine, in accordance with the boundary conditions, the components of stress and displacement. W. Ornstein, USA

384. Sternberg, E., and Rosenthal, F., The elastic sphere under concentrated loads, *J. appl. Mech.* **19,** 4, 413–421, Dec. 1952.

This paper is one of more than passing interest in elasticity theory. First of all, it contains the solution of a classical problem of some difficulty and practical application. Further, it is the first correct solution to be published on the subject of a force acting at a point on a curved bounding surface. Finally, and perhaps most important, the very nature of the problem has led the authors to uncover and dispose of a very interesting situation concerning concentrated forces.

The necessity for and the technique of specifying the nature of a concentrated force appear to have been understood by early workers in the field, but, as the years rolled by, a new method for obtaining old solutions was adopted quite generally. The later method lacks the essence which made the earlier solutions acceptable and, while the appropriate previous results may be obtained, this can only be through good luck or prior knowledge of the goal. When a new problem is attacked, prior knowledge of its solution is not available, and the luck is likely to be bad, as in a recent paper to which the authors refer.

The source of the difficulty is the customary incomplete statement of the uniqueness theorem, if it is considered at all. Involving, as it does, an application of the divergence theorem, the uniqueness theorem in its usual form [Love, "Theory of elasticity," 4th edition, 1927, p. 170] must be supplemented by statements regarding singularities, continuity, and behavior at infinity. Thus, in the present case, the full uniqueness theorem includes the requirement that the singularity appropriate to the single force be specified. However, the theorem does not supply the appropriate singularity. It simply says one must be specified. The question remains, then, "What is a single force?"

In the first single-force solution to be obtained, Kelvin adopted, as the definition of a single force within a body, the limit, of a distribution of parallel body forces in a bounded volume, as the volume shrinks to a point while the resultant force remains constant [Love, op. cit., p. 184]. Similarly in the problem of Boussinesq and Cerruti, relating to a force acting at a point on a plane bounding surface, the defintion is the limit of a surface distribution of traction over an area, as the area is shrunk to a point while the resultant of the tractions remains constant [Love, op. cit., p. 242]. These are sensible definitions, on physical grounds, and they lead to specific singularities, as required by the uniqueness theorem. Any number of other singularities could be added without violating the requirement that the combination have a force resultant; but none of these would conform to the original definitions. Hence, the answer to the question raised by the uniqueness theorem is: "A single force is what we shall agree it is, provided our definition leads to a unique singularity." Any definition which does not lead to a unique singularity is in violation of the uniqueness theorem.

The first violator appears to have been Boussinesq himself, and his erroneous method is given, without comment, by Love [op. cit., p. 191] along with a correct procedure [op. cit., p. 242], and by Timoshenko and Goodier ["Theory of elasticity," 2nd edition, 1951, p. 362]. The erroneous feature of the "method of superposition of nuclei of strain" is that the singularity is tested only for its resultant, and there are many singularities with the same resultant. The same criticism can be directed at the treatment of Kelvin's problem by Timoshenko and Goodier [op. cit., pp. 354–356]. That such criticisms are not finicky is shown by Sternberg and Rosenthal when they call attention to the inacceptability of a recent treatment of the problem of a heavy sphere supported at a point [W. Leutert, *Pacific J. Math.* **1,** 1, 97–101, 1951].

Sternberg and Rosenthal find that the singularity appropriate to a normal force at a spherical surface is not the same as the Boussinesq singularity, but differs from it by weaker singularities. Leutert's force, however, contains stronger singularities than Boussinesq's. As evidence in support of their result, the authors show that their singularity is the one obtained as the limit of a distribution of normal tractions over a spherical cap as the cap shrinks to a point while the resultant force remains constant. Thus, their singularity is correct if Boussinesq's is, since both, although different, stem from the same definition. Hence, they are able to show that, as the radius of the sphere approaches infinity, their singularity approaches Boussinesq's, whereas Leutert's does not.

To complete the argument, it is necessary to agree on a definition of single force. But what sensible definition could there be, other than one of the type initiated by Kelvin?

In addition to the formal solution of the problem and the discussion of the single force, the paper contains numerical results for stresses in the sphere. The normal tractions on the equatorial plane, obtained from photoelastic measurements, are found to agree quite well with the mathematical values. The authors also show that, if Leutert's singularity is used, the maximum normal traction on the equatorial plane differs from theirs by a factor of four, despite the fact that the singularities differ only by a self-equilibrating system of forces. R. D. Mindlin, USA

385. Takahashi, S., Anelasticity of zinc, *J. appl. Phys.* **23,** 8, 866–868, Aug. 1952.

Anelastic properties of zinc single crystal of high purity (99.996%) have been studied, using bars vibrating transversely at audiofrequencies in free-free modes. Internal friction, effective elasticity, and shape of resonance curve were determined against the strain amplitude. When the driving force exceeds a critical value, the internal friction increases, its maximum-amplitude-frequency decreases, and its resonance curve becomes asymmetrical. Furthermore, under this condition, a discontinuous phenomenon, which is supposed to be closely correlated with slips occurring in the crystal, has been found. This discontinuous phenomenon was recorded under different stresses.

From author's summary

Experimental Stress Analysis

(See also Rev. 409)

386. Hickson, V. M., Errors in stress determination at the free boundaries of "frozen stress" photoelastic models, *Brit. J. appl. Phys.* **3,** 6, 176–181, June 1952.

The magnitudes of the errors, apart from those due to imperfect material, which may occur in the determination of free boundary stresses from direct relative retardation observations, are estimated with particular attention to the case of a stress concentration. Errors discussed are: (A) Measurement errors: (1) Measurement of the thickness of the slice, (2) location of aperture with respect to the reference point, (3) angle settings of the slice with respect to the incident ray, (4) polariscope errors, leading to errors in tardy compensation, (5) finite size of photometer aperture. (B) Errors due to finite thickness of slice: (1) Variation of magnitude of stress through the thickness of the slice, (2) change in directions of principal stresses through the thickness, (3) tardy com-

pensation error due to rotation of polarization planes through the thickness.

Experimenters in the field of three-dimensional photoelasticity will profit from this careful study. Reviewer notes that, whereas items (B) are considered independently, their importance is actually determined by the magnitude of a ratio whose numerator is the rate of rotation of the secondary principal axes through the thickness, and whose denominator is the rate of relative phase retardation that would obtain in the absence of rotation [see AMR 2, Rev. 579]. Lawrence E. Goodman, USA

387. **Benito, C., and Moreno, A., Three-dimensional photoelastic studies with gelatin models** (in Spanish), *Lab. Centr. Ens. Mater. Constr. Madrid Publ.* no. 73, 34 pp., 1951.

In the first part of this paper, authors deal in a very general way with several methods commonly used in three-dimensional photoelasticity. In the second part, several kinds of gelatin are systematically studied and their use in three-dimensional photoelasticity is suggested. The authors find that the modulus of elasticity of some gelatins and their fringe value increase about 20 times when the temperature decreases from 20 C to 2 C. It is suggested by them that the "freezing" of the stresses be accompanied by dropping the temperature rather than by heating, as in the conventional technique when plastics are used to make the models. Many advantages of this method are pointed out. Complicated shapes can be easily cast from inexpensive material; models can be made in large sizes, thus increasing accuracy; slices can be cut easily by means of a wire and do not have to be polished; and stresses produced by gravity force can be determined. The main limitation is the very large deformations of the models.

Authors also study the optical creep in the gelatin, and indicate it to be proportional to stress. They therefore conclude that gelatin can be used accurately for photoelastic tests. This is a similar conclusion to the one reached by the reviewer after studying Catalin and Marblette.

After studying different compositions of gelatin, authors conclude that the best mixture for three-dimensional photoelasticity is the following: 35% of gelatin and a proportion of 0.5 for glycerine/water.

Authors apply their method to the determination of stresses in a semi-infinite block under a load uniformly distributed on a circle. They claim that their experimental results show a difference of only 4% as opposed to theoretical findings. This is surprising, however, since the theoretical solution used gives values of the maximum shear for the axis of symmetry, and, according to Fig. 25, the slice used by the authors is as thick as the diameter of the circle. A. J. Durelli, USA

388. **Schäfer, A., Photoelastic behavior of celluloid and dekorit** (in German), *Ing.-Arch.* **20**, 2, 81–87, 1952.

Examination of artificial double-refraction in celluloid and dekorit (with several states of hardness) is made by use of a standard beam under pure traction. Simultaneous measurement is taken of the strain. Author studies the dependence of the optical effect on time in the case of a constant load. Author considers the physical significance of the results obtained.

H. Favre, Switzerland

389. **Tokarcik, A. G., and Polzin, M. H., Quantitative evaluation of residual stresses by the stresscoat drilling technique,** *Proc. Soc. exp. Stress Anal.* **9**, 2, 195–207, 1952.

Residual stress evaluation by drilling small holes in the subject piece and measuring strain relaxation around the hole by stresscoat cracking patterns has been previously described. The present authors experienced difficulty applying the technique to magnesium alloy, since strain patterns were produced apparently by cold-working in the vicinity of the hole during drilling. Paper presents calibration curves for uniaxial stress obtained by comparing cracking patterns with measured strains in test pieces drilled in loading fixtures. Magnesium, aluminum, and steel were used. The procedure is apparently insensitive to small residual strains and shows a scatter range of $\pm 25\%$ to $\pm 50\%$ at higher strains. As an indication of whether or not high residual strains are present, the procedure and data here presented are useful.

H. A. Lepper, Jr., USA

390. **Gross, N., and Lane, P. H. R., Stress-probing: a rapid method for stress-surveying,** *Engineering* **174**, 4513, 97–100, July 1952.

Measurement of stresses in vessels or tubular components requires many measuring stations. When electrical resistance strain gages are applied, time for their installation is considerable, and after measurement the gages are valueless. T. S. Robertson suggested another "stress-probing" method, in which only one mechanical gage is applied successively to all measuring stations, but the test specimen must be slowly loaded periodically during the test. Authors apply this method, using a new mechanical measuring device attachable by a magnetic clamp. Readings at many stations can be taken with the magnet in the same position, and measurement can be performed quickly and economically. Results of stress-probing and strain-gage measurements are compared and show small differences.

P. Kohn, Czechoslovakia

391. **Cook, P. M., and Wistreich, J. G., Measurement of die pressures in wire drawing by photoelastic methods,** *Brit. J. appl. Phys.* **3**, 5, 159–165, May 1952.

Paper is devoted mainly to describing test and computational procedures. It also contains a brief reference to drawing theory.

To compare experiment and theory, author calculates the pressure between wire and die from the stress pattern of a wedge-shaped die made of photoelastic material. A lead-tin alloy wire was drawn through the die, and the stress pattern was recorded during the motion of the wire. Two photoelastic materials were used, C.R.39 (allyl styrene resin) with high optical sensitivity, and Perspex. The isochromatics were recorded with the C.R.39, and the isoclinics with Perspex. The photographic prints were made on sensitized aluminum to avoid change in dimensions.

Filon's transformations of the Lamé-Maxwell equation were used as computational procedure. In author's opinion, this was the most adequate method according to the circumstances of the test. The features of the calculation are discussed in detail, showing the changes introduced to standard methods to overcome the difficulties of this particular case. Alternative paths of integration were used. The values of principal tensions q obtained by two ways, from the p values and by direct integration, were employed as calculation checks.

Experimental data are shown to be in good agreement with the theory of drawing due to Hill and generalized by Green.

C. A. Sciammarella, Argentina

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 376, 429, 436, 457, 490, 508)

392. **Kosmodamianskiĭ, A. S., Bending of a plane curved anisotropic beam by a force applied at the end** (in Russian), *Prikl. Mat. Mekh.* **16**, 2, 249–252, Mar./Apr. 1952.

Author solves the state of stresses for a curved beam fixed at one end and free on the other with any load on the free end; the

material of the beam is anisotropic, consisting in layers separated by cylindrical surfaces concentric with the inner and outer surface of the beam. From the stress function are derived normal and shearing stresses in radial sections. For a small ratio of outer and inner radius of the beam, the distribution of normal stresses in radial section approaches linear law, and the distribution of shearing stresses is near a parabolic law, as for straight beams.

Z. Bažant, Czechoslovakia

393. Baldacci, R. F., Contribution to the dynamics of a beam on elastic foundations (in Italian), *Atti Accad. Sci. Torino* **85**, 111–126, 1950–1951.

The beam rigidly supported at the ends and elastically over its whole finite length is analyzed in the following way: (1) Free vibration in the absence of outside perturbations. The differential equation of the movement with partial derivatives is studied in its homogeneous form, and, the solution being given for the product of two functions, each with one single variable, two differential equations with total derivates are obtained, each of them allowing to deduce the individual values and, thus, the general values of the deflection. (2) Forced vibration, introducing an outside perturbation of a concentrated load with uniform speed along the beam and of variable intensity with harmonic law. Lagrange's equations in normal coordinates φ_k are established, and particular solutions are given for a series which agrees with Timoshenko's solution for the case of constant intensity.

The case of the forced vibration of a beam on elastic foundation and infinite length is then analyzed on the basis of the given solution for finite length by changing the origin of coordinate axis. At the limit, the Fourier series are transformed into Fourier integrals whose values are discussed to obtain the deflection. Finally, the critical condition is established for the infinitely long beam, expressed by its velocity.

Arturo M. Guzmán, Argentina

394. Jourdain, M., Straight beam with constant moment of inertia resting on an elastic foundation (in French), *Bull. Assn. tech. marit. aéro.* no. 50, 567–586, 1951.

The well-known solution of the differential equation $EI \cdot y^{IV} + k \cdot y = 0$, of a straight beam on elastic foundation for a concentrated load is given. To find the corresponding solution for several concentrated loads by superposition and by avoiding the rather tiresome application of formulas, graphical diagrams for various possibilities are established. For practical application, the scale of the given diagrams is somewhat insufficient.

F. Stüssi, Switzerland

395. Mayfield, B., and Coates, R. C., Fixed end moments in beams with linear haunches, *Engineering* **174**, 4512, 68–69, July 1952.

General expressions, in terms of column analogy, are developed for end moments and moment distribution carry-over factors. These apply to beams having a central portion of constant depth with ends of linearly increasing depth. Influence lines are drawn for two specific beams showing very good experimental checks.

Designers of haunched structures should find these equations useful in practice. C. M. Tyler, Jr., USA

396. Tremmel, E., Thermal stresses in composite beams (in German), *Öst. Bauzeitschr.* **7**, 1, 1–5, Jan. 1952.

Forces and moments acting on flanges and webs of tee beams caused by differences in temperature gradients in these two parts are calculated. Formulas also are derived for resultant elongation and curvature of beam. Results are presented in form applicable to any composite beam. G. Sved, Australia

397. Corten, H. T., Clark, M. E., and Sidebottom, O. M., Peculiar behavior of steel beams under dead loads that produce inelastic strains, *Trans. ASME* **74**, 3, 349–354, Apr. 1952.

Paper presents results of bending tests on mild-steel and rail-steel beams of rectangular, circular, and I cross sections with emphasis given to effect of time on load-deflection characteristics. Strains and maximum deflections are measured on beams with four-point loading such that center span is subjected to constant bending moment. Dead-weight loading is applied in increments, with each increment applied after cessation of inelastic deformation resulting from previous increment. Results are presented as curves of dimensionless bending moment M/M_e against dimensionless strain ϵ/ϵ_e or dimensionless deflection Δ/Δ_e, where M is maximum bending moment, M_e maximum elastic bending moment, ϵ strain at outermost fiber, ϵ_e maximum elastic strain, Δ deflection at center of constant-moment span, Δ_e maximum elastic deflection.

Curves have stair-step appearance under this loading schedule, and show inelastic deformations measured by ϵ/ϵ_e or Δ/Δ_e of order of ten in mild steel near plastic hinge. Comparison with theoretical curves based on idealized "sharp-knee" tensile and compressive stress-strain curves show that experimental moments fall short of theoretical values in mild-steel specimens. Authors attribute this to nonhomogeneous yielding. Phenomenon is not apparent in 0.8% carbon rail steel. Curves plotted show increase in strain at a given moment as function of time. In mild-steel beams at plastic hinge, considerable delay (about 30 minutes) occurs after load application before plastic deformation starts. Delay varies with magnitude of load increment. No appreciable delay is apparent for rail-steel specimens.

Walter C. Hurty, USA

398. Craemer, H., Efficiency lines as means of representation in plastostatics (in German), *Ing.-Arch.* **20**, 2, 129–135, 1952.

The efficiencies of beams in an elastoplastic state are studied. The efficiencies ν, μ, and ω are defined as $\nu = \sigma/\sigma_s$, $\mu = M/M_s$, and $\omega = P/P_s$, where σ is the stress at any point of the beam section, M is the moment at the section, P is the beam load, and the subscript s stands for the ideal-plastic state. Relationships between ν and ω, and ν and μ are derived for I and triangular beams, with the following support and load conditions: both ends fixed, two equal loads at the third-points along the length; both ends fixed, one load at a third the length from one end; three simple supports, one of them in the middle, and two equal loads located symmetrically about the middle support at a distance of a sixth the beam length. The relationships are analyzed graphically for various values of ν, μ, ω, and beam dimensions and the conditions for the setting-in of the plastic state are established. D. Kececioglu, USA

399. Konarzewski, Z., Trajectories of principal stresses in prestressed beams (in Polish), *Inżyn. Budown.* **9**, 5, 175–177, May 1952.

Purpose of paper is to calculate and to draw trajectories of principal normal and shearing stresses in a freely supported horizontal beam of rectangular cross section uniformly loaded along its span and compressed longitudinally by an eccentric horizontal force. Author applied well-known elementary formulas for normal and shearing stresses. Moment due to longitudinal force is calculated under the assumption that the axis of the beam is a straight line (linear approach). Nonlinearity due to deflected axis and its influence upon the bending moment are ignored, the law of superposition holds; hence, solution represents only first approximation. Calculations and diagrams are presented for a few ratios of uniform compressive stress in the bottom fiber due to

compression force only, and maximum compressive stress due to bending only. The final goal is to construct reinforced-concrete beams having no tension stresses parallel to the axis.

M. Z. Krzywoblocki, USA

400. **Dobie, W. B., and Gent, A. R., Accuracy of determination of the elastic torsional properties of non-circular sections using relaxation methods and the membrane analogy,** *Struct. Engr.* **30,** 9, 203–212, Sept. 1952.

Authors discuss an application of membrane analogy and relaxation procedure to Saint Venant torsion stress and stiffness analysis of arbitrary cross sections. Discussion is centered around circular section with longitudinal circular notch, for which an analytical solution is available. Corrections for errors in volume (stiffness) and slope (stress) measurements due to finite height of membrane are developed and are based on a comparison of infinitesimal and finite height solutions for the circular membrane. Numerical solution by the relaxation technique is also obtained for same section. Results indicate that, by both methods, stresses and stiffnesses can be obtained within a few per cent of the theoretical values. J. E. Duberg, USA

401. **Mii, H., Plastic deformation of light-metal bar strained with combined tension and torsion (2nd report). Theory of inverse loading,** *J. Japan Soc. appl. Mech.* **5,** 27, 13–15, 1952.

An analysis is given for the stress and strain distribution in a bar under reversed loading after being deformed under tension and torsion in plastic range. Plastic deformation theory, with maximum shear stress-strain relation of the material as the criterion, is used. The reversed pull and twist are assumed to apply simultaneously and the reversed longitudinal strain is assumed to be uniform across the section.

A numerical example is given on the calculation of residual stress and strain in a bar after being deformed in plastic range under tension and twist, with the assumption of linear stress-strain relationship at the primary stage of reversed loading.

T. H. Lin, USA

402. **Cutts, C. E., Horizontally curved box beams,** *Proc. Amer. Soc. civ. Engrs.* **78,** Separ. no. 128, 18 pp., May 1952.

A box beam curved horizontally through an angle of 90° and resting on four supports is analyzed for maximum torque, shear, moment, deflection, and rotation, when the beam carries a uniform load. Warping of the section due to torsion is taken into account. Three types of box beams were fabricated and tested. Calculated and test results show a good comparison for deflection, but a poor one for rotation and secondary warping stress.

R. J. Legger, Holland

403. **Lattanzi, F., Application of the theory of the transverse elasticity ellipse to the study of a curved rod elastically constrained at the ends** (in Italian), *Atti Accad. naz. Lincei R. C. Sci. Fis. Mat.* (8) **10,** 5, 395–400, May 1951.

404. **Lattanzi, F., Application of the theory of transverse elasticity ellipse to the study of a curved rod elastically constrained at the ends** (in Italian), *Atti Accad. naz. Lincei R. C. Sci. Fis. Mat. Nat.* (8) **11,** 3/4, 178–186, Sept./Oct. 1951.

See AMR **5,** Rev. 2306.

405. **Ryan, J. J., Characteristics of dished-plate (Belleville) springs as measured in portable recording tensiometers,** *Trans. ASME* **74,** 4, 431–438, May 1952.

Author describes a portable recording tensiometer consisting essentially of a stack of Belleville springs, the deflection of which is a measure of the load. Deflection of these springs is measured by scribed lines on a film driven by a clockwork mechanism; in this manner, impact loads may be determined. Deflection test data are presented on a range of sizes of Belleville springs; comparison of test results with values calculated, using various available formulas (flat-disk, Almen-Laszlo, circular ring), indicates satisfactory agreement for cases tested where deflections were small compared to spring thickness. Author suggests such springs may be useful in other machine-design applications. A. M. Wahl, USA

406. **Iredell, R., Elastic rubber cushion springs for torque load applications,** *Prod. Engng.* **23,** 3, 119–123, Mar. 1952.

Description of a torsion spring featuring polygonal inner and outer shells with rubber rollers acting as the elastic elements.

The ultimate design load is found to vary as the square of the roller diameter. The length-to-diameter ratio of the rollers depends on particular application considerations, e.g., 3 for couplings, and 8 to 10 for vehicular suspensions.

Conrad C. Wan, USA

407. **Weydert, J. C., Stress charts for pressurized elliptical and oblong tubes,** *Prod. Engng.* **23,** 6, 195–199, June 1952.

Nomogram and chart are given for the determination of the maximum stress in tubes that are either elliptical or oblong when the tubes are subjected to internal pressure loading.

Conrad C. Wan, USA

408. **Wolff, P. H. W., The design of flexible disk misalignment couplings,** *Instn. mech. Engrs. appl. Mech.* **165** (W.E.P. no. 67), 165–173, Proc. 1951.

Problem of flexible disk coupling is analyzed by thin plate theory. Disk is idealized to one with clamped inner and outer boundaries. Power-law variation of disk thickness is assumed. Two types of transmission of load are considered, producing the so-called umbrella-type (longitudinal shaft movement) and skew-type (angular shaft movement) deformations of the disk. It is found that the important stresses to be considered in design are radial-bending and tangential-bending stresses; centrifugal stresses and torsional shear stresses are negligible for ordinary usage of such couplings. These stresses must be kept below the fatigue limit for the material. The vibration characteristics for skew deformations and the buckling due to applied torque are also considered in the design. H. J. Plass, USA

Plates, Disks, Shells, Membranes

(See also Revs. 339, 378, 384, 405, 408, 646)

409. **Dantu, Experimental study of plates by an optical method** (in French), *Ann. Ponts Chauss.* **122,** 3, 271–344, May/June 1952.

Author reports a series of experimental studies for the moments and curvatures in thin plane plates as obtained by an optical method which was described in *Annales des Ponts et Chaussées* [June 1940]. This optical method employs a reflecting glass plate, a mirror above the plate and rotated 45° with respect to the plate, and a wall screen upon which the distorted grid of the plate face is projected. Upon loading the plate, any rotation of the plate normal will cause a displacement of the reflected optical ray on the screen. By measuring linear and angular variations of the grid deformations on the screen, the curvature tension components of the plate are found.

The method was applied to circular and rectangular plates under uniform and concentrated loads and with a variety of edge constraints. Another series of studies includes plates on elastic

subgrades. Some correlation is found with the results of Westergaard for central, edge, and corner loads on rectangular plates which are supported on an elastic base. D. L. Holl, USA

410. Hearmon, R. F. S., and Adams, E. H., The bending and twisting of anisotropic plates, *Brit. J. appl. Phys.* **3,** 5, 150–156, May 1952.

Experimental data on metal and plywood plates are given to test the validity of the theory, which could thus be confirmed.
F. Schultz-Grunow, Germany

411. Langhaar, H. L., Note on energy of bending of plates, *J. appl. Mech.* **19,** 2, p. 228, June 1952.

The strain energy of bending of a flat isotropic elastic plate of constant thickness is $U_b = 1/2D\int_A\int(1/r_1^2 + 1/r_2^2 + 2\nu/r_1r_2)\,dA$. If the middle surface of the plate is simply connected, and the bounding curve C of the deformed middle surface is composed of several smooth arcs, the expression for U_b may be transformed by the Gauss-Bonnet theorem to the form, neglecting additive constants, $U_b = 2D\int_A\int M^2dA + D(1-\nu)_c\int\kappa_g ds$, where $M = 1/2(1/r_1 + 1/r_2)$ and κ_g is the geodesic curvature of the curve C on the deformed middle surface of the plate.

Author points out several cases where the line integral of κ_g is zero or is independent of deflection, so that $U_b = 2D\int_A\int M^2dA$.
D. H. Winne, USA

412. Huang, M. K., and Conway, H. D., Bending of a uniformly loaded rectangular plate with two adjacent edges clamped and the others either simply supported or free, *J. appl. Mech.* **19,** 4, 451–460, Dec. 1952.

Authors present a series solution to each of the two problems (small deflection theory) mentioned in the title (the other sides are either both simply supported or both free). Solutions are found by superimposing the deflection of uniformly loaded and line-loaded plates [see AMR **4,** Rev. 1339] and using symmetry. Numerical values are given for the deflection and bending moments for square plates. Results for the simply supported case are compared with those obtained by Stiles' method.
C. L. Perry, USA

413. Sengupta, H. M., On the bending of an elastic plate. II, *Bull. Calcutta Math. Soc.* **43,** 123–131, 1951.

In an earlier paper [AMR **4,** Rev. 1076], author solved the problem of a thin clamped elliptic plate subjected to a normal concentrated loading acting at any point on its surface. Making use of this solution and applying two symmetrically disposed loads, author extends results to include (a) semi-elliptic plate clamped at elliptic edge and supported on major axis, (b) semi-elliptic plate clamped at elliptic edge and supported on minor axis, (c) quadrant of ellipse clamped at elliptic edge and supported on straight edges, each case with a single concentrated load at any point. Unfortunately, no numerical results are given. Author corrects errors and misprints in his earlier paper on elliptic plates. H. D. Conway, USA

414. Ôhasi, Y., Bending of a thin elliptic plate of an orthotropic material under uniform lateral load, *ZAMP* **3,** 3, 212–224, May 1952.

Theoretical solutions are given for both clamped and simply supported elliptical plates of orthotropic material. The axes of symmetry of the material of the plate do not necessarily coincide with the axes of the ellipse. Numerical examples are given.
Gerald Pickett, USA

415. Vlasov, V. S., Basic differential equations in general theory of elastic shells, *NACA TM* 1241, 58 pp., Feb. 1951.

This is a translation of a Russian paper from 1944. All formulas are restricted to orthogonal curvilinear coordinates. The usual assumption of Kirchhoff-Love (normal to the middle surface remains normal and suffers no extension) is generalized by introducing the displacement in the direction of the normal as a linear function of the distance γ from the middle surface. No further assumptions are introduced (except that all deformations are small). Components of strain are then expanded in power series of γ and the first three terms of these series are retained. The resulting system of differential equations is then simplified for shells of "medium" thickness and for "thin" shells. In the latter case, the problem is reduced to two differential equations in a stress function and in the displacement normal to the middle surface. Circular cylindrical shells and spherical shells are dealt with separately. Finally, the problem of stability is considered within the limits of small deflections.

Some progress, of course, has been made since the appearance of this paper, for which the article of Flügge [AMR **4,** p. 489] may be consulted. Heinz Parkus, USA

416. Parkus, H., *Öst. Ing.-Arch.* **6,** 1, p. 76, Oct. 1951.

Correction to paper ("The basic equations of shell theory in general coordinates") reviewed in AMR **4,** Rev. 629.

417. Galimov, K. Z., On the general theory of plates and shells with finite displacements and deformations (in Russian), *Prikl. Mat. Mekh.* **15,** 6, 723–742, Nov./Dec. 1951.

The first and second paragraphs of this paper give a brief exposition of nonlinear theory of shells by using the usual nonsymmetric tensors of tangential forces and moments. For small deformations of the thin shells, these tensors may be considered symmetric in limits of validity of Kirchhoff's hypothesis. In the case of the shell with medium thickness, this simplification causes an error of the order $(h/R)^{1/2}$. Therefore, in the third paragraph there are introduced special tensors of the forces and moments which are symmetric for arbitrary deformations. In the fourth paragraph are deduced the general relationships of elasticity for the isotropic shell. In the fifth paragraph, author shows that the equations of Galerkin in the theory of finite deformations of the shell are not directly connected with the principle of minimum of the potential energy—as in the linear theory. In the sixth paragraph, author introduces a functional R which has a stationary value when the static boundary conditions and the equations of equilibrium are satisfied; its variational equation is $R = 0$. In the seventh paragraph, the functional R is transformed in the shape which does not contain the displacements.
From author's summary by W. Wierzbicki, Poland

418. Salzmann, F., and Kissel, W., Curves for the determination of the stresses in rotating nonuniformly heated disks by the Keller method, *Escher Wyss News,* 23/34, 69–82, 1950–1951.

Authors extend previous work of first author [*Escher Wyss News* no. 3, p. 63, 1938] on Keller's method of determining stresses in rotating disks to include a radial temperature distribution and conical subdisks, with thickness increasing with the radius. J. L. Bogdanoff, USA

419. Ôkubo, H., The stress distribution in an aeolotropic circular disk compressed diametrically, *J. Math. Phys.* **31,** 1, 75–83, Apr. 1952.

A re-analysis of the problem to which approximate solution was obtained by author [*Phil. Mag.* **37,** p. 508, 1939]. Present solu-

tion in series form is exact for the disk of an aeolotropic material which has two directions of symmetry at right angles in the plane of plate. When the two directions of symmetry are parallel to x and y directions, the differential equation governing the stress function is $(\partial^2/\partial x^2 + 1/k_1{}^2\partial^2/\partial y^2)(\partial^2/\partial x^2 + 1/k_2{}^2\partial^2/\partial y^2)\,\chi = 0$, where $k_1{}^2$ and $k_2{}^2$ are related to elastic constants of material. Example considered is a disk of oak, for which the stress distribution is evaluated numerically, using experimentally determined values of k_1 and k_2. Comparison of results is made with a corresponding isotropic material. Paul M. Naghdi, USA

420. **Hemp, W. S., On a theory of sandwich construction,** *Aero. Res. Counc. Lond. Rep. Mem.* 2672, 9 pp., Mar. 1948, published 1952.

Author gives an approximate theory of sandwich plates by means of the assumption that the filling has only transverse and shear stiffness, so that the three components of the stress tensor in the plane of the filling vanish. Buckling and bending problems of plates and circular cylinder shells are treated in this manner. The results are not compared with those of other authors. Also no experiments are referred to. Therefore, reviewer finds that the range of accuracy still cannot be fixed.

H. Neuber, Germany

421. **Chang, C. C., and Conway, H. D., The Marcus method applied to solution of uniformly loaded and clamped rectangular plate subjected to forces in its plane,** *J. appl. Mech.* **19,** 2, 179–184, June 1952.

Authors present a solution to the small-deflection problem specified in the title. An iteration method developed by Marcus was used for the approximate solution of the biharmonic equation. Deflections and moments are presented for a square plate with four particular values of uniform tensile and load, and for the rectangular plate with seven length-breadth ratios and with one value of compressive end load. T. H. H. Pian, USA

422. **Ling, C.-B., On the stresses in a notched strip,** *J. appl. Mech.* **19,** 2, 141–146, June 1952.

In earlier paper [AMR **1,** Rev. 230], author gave solution for strip in tension with semicircular notches. Present paper gives new formulation of equations which avoids necessity of solving simultaneous equations for Fourier coefficients and thus reduces greatly the calculation effort.

Present paper also gives solution for notched strip in pure bending. Comparison between theory and experiment shows reasonable agreement. Stanley U. Benscoter, USA

423. **Baldacci, R. F., A variational method in the plate problem** (in Italian), *Atti Accad. Sci. Torino* **85,** 127–137, 1950–1951.

Similar to the method of E. Trefftz for the torsion problem [*Proc. sec. int. Congr. appl. Mech.*, 131, 1927], author approximates solution of biharmonic boundary-value problem by means of biharmonic functions, not necessarily satisfying boundary conditions. Corresponding variational problem is thus transformed so as to give lower bounds for solution when attacked by direct method. F. K. G. Odqvist, Sweden

424. **Vasarhelyi, D., and Hechtman, R. A., Welded reinforcement of openings in structural steel members,** *Weld. J.* **31,** 4, 169s–180s, Apr. 1952.

Title is misleading since paper deals with tests to determine unit strain energy and true stress distribution in plastic region of a flat plate with an *unreinforced* square opening with rounded corners. Natural strain distributions were obtained from tension tests to failure of two such specimens of structural steel at temperatures of 76 F and −20 F. True stress and unit strain-energy distributions were calculated by use of octahedral shear theory and a set of plastic stress-strain relations derived by authors. An interesting set of unit strain-energy contour plots is given for loads near and at failure, which indicate concentration of energy values at corners of the openings.

Authors conclude that integrated total energy-absorption values agree fairly closely with values obtained from load-average elongation data, although a check of the data revealed discrepancies ranging from +14% to −25%. It is further concluded that 76 F and −20 F specimens absorbed approximately same amounts of energy at the same loads, although discrepancies up to 40% were noted by reviewer. George Gerard, USA

Buckling Problems

(See also Rev. 446)

425. **Tyler, C. M., Jr., and Christiano, J. G., An Airy integral analysis of beam columns with distributed axial loading having a fixed line of action,** *J. appl. Mech.* **19,** 3, 275–283, Sept. 1952.

Paper deals with solution of beam-column problem in which a uniformly distributed axial load is applied in equilibrium with axial end loads. It is assumed that the line of action of axial load remains straight as column deflects. Differential equation governing deflection is one having been previously studied; its solutions, the Airy integral functions, have been computed. Author includes a rather complete table for convenience. Condition for instability is expressed in terms of these functions. Paper includes worked example of such a beam column having a single concentrated lateral load. H. J. Plass, USA

426. **Feigen, M., Minimum weight of tapered round thin-walled columns,** *J. appl. Mech.* **19,** 3, 375–380, Sept. 1952.

On the basis of specifying that the stress in an optimum structure will be at a maximum in all parts of the structure so that incipient failure can occur simultaneously in all parts, the following results have been obtained: (1) Optimum wall thickness of a cylindrical round tube column is a function of the load only, and independent of the diameter, and for tapered thin-walled column is constant along its length; (2) optimum shape of a tapered thin-walled column is determined by obtaining a bending stress in the buckled state constant along its length; (3) the weight ratio of the optimum tapered column to an equal-strength optimum cylindrical column is 0.8924; (4) in the inelastic range, the weight advantage of the tapered column will be less than in the elastic range.

The work of a few other investigators is also reviewed; the comparison of a cone with an equal strength cylinder is presented.

F. K. Teichmann, USA

427. **Cicala, P., On a buckling problem in the elastoplastic range** (in Spanish), *Monogr. Lab. Aero. Politec. Torino* no. 269, 16 pp. = *Rev. Fac. Cienc. exact. fis. nat. Univ. Cordoba* **14,** 1, 1951.

In a previous paper [see AMR **4,** Rev. 2436] author considered the buckling of a sheet strip compressed in the longitudinal direction, with one of its long edges free and the other simply supported. He assumed, since the strip was considered very long compared to its width, that it was possible to study buckling by taking into account only the axial stresses and the tangential stresses resulting from torsion. It was further assumed that, even taking into account the variation of the modulus of rigidity with the applied force, the relation between tangential stress and

corresponding stress is the same at all points of the plate. The latter assumption is eliminated in the present paper.

The local shear rigidity is considered as a function of the ratio of axial to tangential stress rates in accordance with a theory of plastic slip proposed by S. B. Batdorf and B. Budiansky. The increment of stress corresponding to incipient twist is analyzed for the case of a prismatic bar compressed beyond the elastic limit. If a certain parameter defined by the author is considered as a small quantity, first-order corrections to Saint Venant's torsion problem, due to inelastic behavior, can be expressed as shown, and the torsional stiffness—a function of the ratio of simultaneous increments of axial load and twist—can be calculated when the solution to the elastic problem is known.

On the basis of the above-mentioned results, the buckling of a sheet strip subjected to longitudinal compression, while one of its long sides is free and the other simply supported, is investigated. The buckling appears to start at the secant modulus value of axial stress and proceed with rapidly increasing twist as the stress exceeds this value. J. P. Michalos, USA

428. Munakata, K., On the vibration and elastic stability of a rectangular plate clamped at its four edges, *J. Math. Phys.* **31, 1, 69–74, Apr. 1952.**

The rectangle of the plate is mapped conformally into a circle, and the resulting differential equation (considerably more complicated than the ordinary biharmonic equation) is treated approximately by Galerkin's method. Solutions are expanded in the eigenfunctions of the clamped circular plate. It is necessary to solve a determinantal equation in which coefficients are obtained by numerical integration to find natural frequencies and buckling load. Method does not seem to reviewer to offer an advantage over a direct numerical approach without conformal mapping of the rectangle. Robert E. Roberson, USA

429. Davidson, J. F., The elastic stability of bent I-section beams, *Proc. roy. Soc. Lond.* (*A*) **212, 1108, 80–95, Apr. 1952.**

The lateral buckling of an I-section beam bent by pure couples in the plane of its web is considered. The analysis is a combination of the method of Reissner and Grober, who discussed beams of rectangular section and hence neglected bending deformation due to torsion, and the method of Timoshenko, who considered the shearing action in the flanges of the I-section beam, but included a restriction that the beam remain straight until instability occurred. Author removes these restrictions and treats the end conditions in the most general manner.

The result shows that the critical moment depends upon the fixity of the individual flanges as well as of the whole beam at the ends, and has been verified by experiments. When the principal flexural rigidities of the section are of the same order, so that the curvature in the plane of bending is large, a modification of the end conditions given by previous writers for both I- and rectangular-section beams is necessary. This modification is insignificant in practical cases. T. H. H. Pian, USA

430. Wang, C.-T., and Sullivan, D. P., Buckling of sandwich cylinders under bending and combined bending and axial compression, *J. aero. Sci.* **19, 7, 468–470, 485, July 1952.**

Paper concerns calculation of buckling load of sandwich cylinder having weak core. Starting with the Donnell equilibrium equation modified to include effects of transverse shear, as was done by Stein and Mayers [AMR **4,** Rev. 625], authors specialize to case of combined bending and axial compression. Bending stresses in sandwich faces are neglected; only membrane stresses are considered. Buckling is assumed in form of m half waves axially, with undetermined amplitude circumferentially, expressed by means of Fourier series with unknown coefficients. Galerkin's method is used to obtain equations for the coefficients. Determinant of coefficient array is set equal to zero to obtain buckling load. Authors find that buckling takes place with many half waves axially, the critical combination of axial force and bending moment being that which produces a maximum compressive stress equal to that for buckling under pure compression.

Reviewer finds a mathematical inconsistency not treated by authors. In carrying out approximate solution of algebraic equations for Fourier coefficients, it is found that the coefficients are all of the same magnitude, possibly with alternating signs; hence, Fourier series fails to converge. However, authors substitute series in Donnell's modified equation which requires derivatives of eighth order. H. J. Plass, USA

Joints and Joining Methods

431. Williams, D., Load distribution in riveted and spot-welded joints, *Instn. mech. Engrs. appl. Mech.* **165** (W.E.P. no. 66), 141–147, Proc. 1951.

Theoretical treatment of title subject is based on experimentally obtained load-deflection curves for riveted and spot-welded joints. Two simplified examples are presented: A multirow lap joint, and a stringer-reinforced tension panel with appreciable shear lag. For static loading, riveted joints show higher ultimate strength than corresponding spot-welded joints despite the fact that the spot-welds have a failure stress twice as great as that of the rivets. This is due to the "give," or what authors calls "shear flexibility" in the riveted joint which results in a more agreeable load distribution than that for the spot-welded joint. However, damage to the edges of the countersunk holes produces a low and early yield point for the rivets, whereas the spot welds have a yield point close to the ultimate stress. This is of importance for repeated loading of small magnitude under which conditions the welds show better performance than the rivets. Author emphasizes that "the character of the loads to which a structure is likely to be subjected, determining as it does the relative importance of ability to reach a high static failing load and capacity to stand up to constant repetitions of small load, must be considered in the choice between a riveted and spot-welded structure." Paper is clearly presented and should be of interest for design of connections of aircraft elements and light-gage steel construction. Gordon P. Fisher, USA

432. Watanabe, M., General analysis of welding stresses and their applications, *Japan Sci. Rev.* **2, 2, 139–146, Aug. 1951.**

Author considers effect of thermal expansion and plastic flow on residual stresses and strains developed in welding. Case of wide plate heated along both sides of a narrow central strip is studied analytically and experimentally, with fair agreement between measured and calculated stresses.

W. O. Richmond, Canada

433. Stern, E. G., Fundamental considerations in the design of nailed structures, *Civ. Engng. Lond.* **47,** 547, 548, 549; 62–63, 145–146, 230–233; Jan., Feb., Mar. 1952.

Author discusses the results obtained in the last few years on the behavior of nailed joints either in research laboratories or executed designs.

American and European specifications are discussed with particular references to the German code, partially transcribed, and to the bibliography on the subject written in that language. Nailed connections, because of their simplicity and the efficiency

shown in important structures, and used especially in Europe, receive increasing support from designers. Author sponsors the use of helically and annularly threaded-shank nails in order to improve the axial withdrawal resistance and the lateral load-carrying capacity. Besides, if nails are hardened, the rigidity of the joint is also improved. H. O. Albano, Argentina

434. Stoy, W., and Mlynek, F., Let-in and pressed-in fasteners for timber structures (in German), *Bautechnik* **29,** 9, 241–246, Sept. 1952.

A well-illustrated survey is made of timber connectors in use. The inserted fasteners include carpenter, T-profile, double-cone, claw-ring-plate, split-ring (Tuchscherer, Beier, Schueller, Hess, Locher, Appel, Rigling, and Hartl types), reinforced-ring (Appel, Christoph, and Unmack), and claw-ring dowels. The pressed-in fasteners include square and round clamping plates (Bulldog, Treiber, Panther, Pfrommer, and Rox types), toothed rings (Luer, Alligator, and Geka types), spiked rings, square and round spike grids, and spiked spirals.

While these connectors are used extensively in Europe, only a few of them are known in the United States, according to the experience of the reviewer. E. George Stern, USA

Structures

(See also Revs. 379, 380, 390, 398, 420, 426, 478, 499, 505, 609)

435. Minkhorst, J. H. K., Nonlinear relationship between loads and deformations of statically indeterminate structures (in Dutch), *Ingenieur* **63, 64;** 42, 13; L.57–L.58, L.1–L.5; Oct. 1951, Mar. 1952.

436. Jäger, K., A more exact method for dimensioning statically indeterminate reinforced-concrete beams (in German), *Öst. Ing.-Arch.* **6,** 3, 223–236, May 1952.

Paper proposes method of calculating bending moments in continuous reinforced-concrete beams taking account of variation in stiffness of the beams due to varying amounts and position of reinforcement. Paper is a logical development of much recent work, including that done by the author on stiffness and deflection of reinforced-concrete beams.

Author begins by relating stiffness of member in zones of positive and negative moment to ultimate flexural strength of member in these zones; then, in a series of equations, he derives expressions for stiffness and carry-over factor of the beam as functions of its stiffness in positive and negative bending. Algebraic solutions are somewhat lengthy, and results are presented conveniently in tabular form. Application of procedure is clarified by worked example. F. A. Blakey, Australia

437. Ensrud, A. F., Analysis of redundant structures by the method of elastic poles, Burbank, Calif., Lockheed Aircr. Corp., 72 pp., 1952.

In 1883, Thomas C. Fidler presented a graphical procedure for analyzing continuous girders [*Proc. Inst. civ. Engrs.* **74,** 1883]. Since then, numerous modifications and variations of Fidler's method have been devised, many of which are summarized in the excellent discussions of a paper by L. H. Niskian and D. B. Steinman [*Trans. Amer. Soc. civ. Engrs.* **90,** 1927]. The paper under review offers another variation in this graphical procedure, together with methods for including the effect of shear deformation and extending the analysis to cover beam columns and columns with elastic supports. The treatment is in handbook form with none of the theoretical background given. It is suggested by the author that the method may be of interest to those structural designers who prefer graphical constructions rather than either analytical methods or numerical iteration and relaxation methods. Dana Young, USA

438. Manning, G. P., The displacement method of frame analysis, London, Concrete Publ., Ltd., 1952, vi + 120 pp. 9s.

Book presents a clear and detailed treatment of slope-deflection method from traditional viewpoint. In addition to rectangular frames with and without sidesway, author discusses frames with sloping members and gives an analogous stress analysis, in the horizontal plane, for vertical flat-sided bins or silos. Particularly useful are the fixed-end moment and stiffness data included by author for nonprismatic members, similar to data available in America from Portland Cement Association. General method was developed independently in 1933 by author, apparently unaware of development by Maney in 1912–1915 and independent development by Ostenfeld. Author solves slope-deflection equations by substitution and elimination, overlooking the possibilities of successive approximation techniques presented by reviewer in 1931–1933. John E. Goldberg, USA

439. Ban, S., Stress redistribution in statically indeterminate rigid frames caused by the creep of concrete, *Japan Sci. Rev.* **1,** 2, 55–61, June 1950.

The Dischinger equations for stress redistribution due to creep are extended to cover frames whose members have differing creep characteristics. The fundamental simultaneous differential equations are derived from consideration of Davis-Glanville and Whitney's laws, and are solved by iteration, two trials usually being sufficient for accurate results. Author works two examples, a rectangular and a pitched-roof portal frame, both subjected to uniformly distributed loading. J. Heyman, England

440. Takabeya, F., and Takabeya, R., Theoretical analysis of Corbusier type frames (in French), *Mem. Fac. Engng. Kyushu Univ.* **13,** 1, 131–158, 1952.

A method of solving Corbusier-type frames is proposed. The problem of the Corbusier frame involves vertical joint translations and, as such, is similar to that of the Vierendeel truss. Essentially, the method represents a systematized technique of solving the classical slope-deflection equations by successive approximations. It differs from moment distribution in that the joint and member rotations are relaxed, instead of the moments. A means of approximating initial values of the joint and member rotations is developed, and an iteration procedure applied to obtain the final values. Once these final values are established, the moments are readily determined by routine substitution into the slope-deflection equations. No new fundamental principles are employed, but the method has merit as a specialized technique. Like all such techniques, its value depends to a degree on the practiced skill of the analyst. J. M. English, USA

441. Cornelius, W., Calculation of underframes by means of the theory of orthogonal-anisotropic plates (in German), *Stahlbau* **21,** 2, 3, 4; 21–24, 42–48, 60–64; Feb., Mar., Apr. 1952.

Author treats the problem of the analysis of bridge floors from a unitary point of view, starting from the fundamental idea that it is advantageous to choose, instead of a system of beam statics, one of continuum statics, the latter based for its solution upon elasticity theory.

The usual method for calculating a gridwork system, treating it as an indeterminate structure, is replaced by one which considers the whole as an anisotropic plate with various flexural rigidities in both perpendicular directions and one torsional

rigidity; for the analysis, it starts from the differential equation with partial derivatives: $B_x\partial^4w/\partial x^4 = (4C + \nu_yB_x + \nu_xB_y)\ \partial^4w/\partial x^2\partial y^2 + B_y\partial^4w/\partial y^4 = p(x)\ 2H = 4C + \nu_yB_x + \nu_xB_y$ (w is deflection; B_x, B_y, C, flexural and torsional rigidities). The usual bridge floors, whether of reinforced concrete, steel, or mixed (e.g., reinforced-concrete plate on longitudinal steel beams, or the same on gridwork of metal beams with or without fixed joints), are grouped into three principal types; for each type, the flexural rigidities and the H value are discussed, the latter giving its own characteristic to the group: (1) $H = (B_x \cdot B_y)^{1/2}$; (2) $0 < H < B_x \cdot B_y{}^{1/2}$; (3) $H = 0$.

In each case the solutions are given of the resulting differential equation, bending moments, twisting moments, shearing forces, and slopes for (1) rectangular plate, (2) plate of infinite length. The analysis has been made for symmetrical and antimetrical linear load of 4 types and one of concentrated load. Two examples illustrate the use of the different tables. In the first, the stresses caused by trucks are determined, and, in the second, the deflections.

Reviewer considers this article an excellent contribution to the general analysis of bridge floors. It may be pointed out that, for building gridwork, reviewer and C. J. Luisoni have studied the advantages of the above equation, but using Galerkin's variational method [AMR **5**, Rev. 417] for the approximate solution.

A. M. Guzmán, Argentina

442. de Pater, A. D., Some new points of view in calculating suspension bridges, *Publ. int. Assn. Bridge struct. Engng.* **11,** 41–110, 1951.

Article contains a deduction of the differential equations which serve as a basis for the calculations. Statical calculations are carried out in the case of various combinations of extensible and inextensible cable with perfectly slack girder. Hereby the horizontal cable deflection is taken into account. The dynamical behavior of the suspension bridge is studied in the case of free vibrations as well as forced vibrations due to a live load moving with constant velocity. As stated by author, the results, contrary to those obtained by K. Klöppel and K. H. Lie [*Ing.-Arch.* **13**, 1942], show that the cable pull and the deflections of the stiffening girder become much greater in the dynamical than in the statical case, and that the suspension bridges with nearly perfect flexible girder are unsuited for railway traffic purpose.

To reviewer, the deduction of the differential equations seems unnecessarily complicated. The equations arrived at are for the statical case recognized as Melan's and Rode's equations [Hans H. Rode, "New deflection theory," *K. norske Vidensk. Selsk. Skr.* no. 3, 1930], Melan's equation being extended to take account of the influence of the effect of an extensible cable. Rode's equation is, however, only used in the case of a perfectly slack girder (putting the flexible rigidity of the girder $EI = 0$). Exact solutions of Rode's equation are, however, given by R. Gran Olsson [*K. norske Vidensk. Selsk. Förh.* **XVII,** no. 2, 1944], which seems to be unknown to author. In this connection it may be of interest to mention that R. Gran Olsson has also given an exact solution for the free vibrations of a suspension bridge with variable rigidity, and it is also possible to find a law of variation of the rigidity covering the range of practical importance for which (in the statical case) exact solutions can be given (to be published).

Leif N. Persen, Norway

443. Barbré, R., Reconstruction of the Luitpold suspension bridge over the Danube at Passau (in German), *Stahlbau* **21,** 1, 2, 4; 9–12, 25–30, 56–60; Jan., Feb., Apr. 1952.

Article contains a broad description of the bridge. Constructional details are given for the bearings of the pavements, the main traffic lane, stiffening girder, cables, tower, and anchorages. Method of erection is also thoroughly described. The stiffening girder is designed without taking account of the influence of the deflection on the bending moments. In part II, there are two misprints in Eqs. (1) and (2) where y'' should be replaced by η''. Article may be valuable as a guide when suspension bridges of similar type are to be designed. Leif N. Persen, Norway

444. Vandepitte, D., The problem of stiffening suspension bridges (in French), *Ann. Trav. publics Belg.* **105,** 1, 133–141, Feb. 1952.

445. Mansfield, E. H., Structural aspects of suction wings, *Aero. Res. Counc. Lond. curr. Pap.* no. 87, 20 pp., 13 figs., 1952.

A proposed method of reducing wing drag involves stabilization of boundary layer by distributed suction. Paper gives estimate of increase in weight of aircraft required to provide porous surface with suction. Increased weight due to suction pump, ducts, porous surface, and supporting structure is estimated as approximately 2% of gross weight. Of the several types of construction considered, a sandwich construction appears most promising. Paper contains solution for flow in a duct with porous walls.

S. U. Benscoter, USA

446. Kuhn, P., Peterson, J. P., and Levin, L. R., A summary of diagonal tension. Part II—Experimental evidence, *NACA TN* 2662, 81 pp. May 1952.

Results are presented of extensive tests made by NACA, various airplane manufacturers, and another research laboratory on plane and curved diagonal tension beams. These test results were used by authors in deriving the empirical relations for analyzing plane or curved shear webs in incomplete diagonal tension, given in part I [AMR **6,** Rev. 91]. Pertinent information relating to specimens, test techniques, tests, and methods of analyzing and evaluating data are presented in great detail. Report summarizes all available experimental work in this field and should be of great value to anyone interested either in improving methods of analyzing web systems working in diagonal tension, or in interpreting specific tests made to demonstrate the strength of a particular new airplane. Wilhelmina D. Kroll, USA

447. Turner, F., An empirical formula for the ultimate shear strength of wing leading edges, *SAAB Aircr. Co. Linköping, TN* 5, 22 pp., 1952.

Report gives an empirical formula for the ultimate shear strength of wing leading edges of 24S-T Alclad, reinforced by conventional ribs and chordwise or spanwise stiffeners. It covers a wide range of the design parameters, including both newer and older wing types. The formula has been checked by a large number of structural tests, the results of which are given in the report.

In the appendix, a brief comparison with the findings of *NACA TN* 2362 is also given. From author's summary

448. Milwitzky, B., and Cook, F. E., Analysis of landing gear behavior, *NACA TN* 2755, 98 pp., Aug. 1952.

A straightforward analysis of the behavior of the conventional type of oleo-pneumatic landing gear during landing impact is presented. The landing gear is treated as a single-degree-of-freedom system prior to the onset of stroking. After the stroking begins, the tire mass and the gear mass are accounted for separately by means of a two-degree-of-freedom analysis. The gear is assumed to be rigid in bending in this report. Some simplified approximations are also presented, and it is found that the system

behavior may be approximately expressed in terms of a single initial-velocity parameter.

Reviewer feels that neglect of the bending flexibility of the gear will introduce significant discrepancies in the stressing of the gear component, such as the drag links. Furthermore, the numerical integration process used may be considerably improved by means of a recurrence formula derived from the consideration of Duhamel's integral. Conrad C. Wan, USA

449. Beaufoy, L. A., Vierendeel truss analysis using equivalent elastic systems, *Publ. int. Assn. Bridge struct. Engng.* **11,** 17–32, 1951.

Author presents a method for the analysis of a Vierendeel truss in which he reduces the analysis of the truss to a solution of several single-bay frames, one for each bay in the truss. The solutions of the various single-bay frames are superimposed upon each other to obtain the complete solution to the problem.

At any particular bay, the Vierendeel truss can be reduced to a single-bay frame consisting of the upper and lower chords, one vertical member which is elastically equivalent to all other bays to the left of the bay in question, and one vertical member which is elastically equivalent to all members to the right of the bay in question. Once having reduced the truss to a single-bay frame, author solves for the effect of the loads acting on the frame by the use of the Hardy Cross method of column analogy. The effect of the loads acting on the frame upon adjacent bays is then obtained by determining the relative displacement of the upper joint with respect to the lower joint at both sides of the panel. Knowing the elastic properties of the Vierendeel truss on either side of the bay in question, the moments induced in the members of adjacent bays due to these relative deformations can be determined. The above procedure is repeated for every bay in the truss. The solution is obtained by a summation of the solutions for individual bays. An example is solved, using a four-bay Vierendeel truss. Karl Arnstein, USA

450. Zangar, C. N., and Haefeli, R. J., Electric analog indicates effect of horizontal earthquake shock on dams, *Civ. Engng., N. Y.* **22,** 4, 54–55, Apr. 1952.

Brief description of device for solving Laplace's equation by measuring electric potential in an electrolytic solution, where boundaries are maintained at potential corresponding to the boundary conditions in the original situation.

M. P. White, USA

451. Perkins, W. A., Analysis of arch dams of variable thickness, *Proc. Amer. Soc. civ. Engrs.* **78,** Separ. no. 129, 29 pp., May 1952.

Author presents a practical method for the analysis of arch dams having thickness variations to allow for the larger moments at the abutments. W. Cain's analysis of circular arches under normal loads [*Trans. Amer. Soc. civ. Engrs.* **85,** p. 233, 1922] is used as a background. The method allows the designer to obtain the stresses and deflections analytically by slide rule. Use of the enclosed curves and abbreviated formulas eliminates the tedious calculations required by the more exacting developed expressions. An illustrative example points out how readily this method can be employed in the design of an arch dam having the most economical dimensions. Clarity of the paper is to be commended. R. E. Heninger, USA

452. Simakov, I. M., Calculation of seepage through earth dams on impervious basis (in Russian), *Gidrotekh. Stroit.* no. 10, 5–8, Oct. 1951.

Author improves mathematical determination of seepage line by introducing, as a variable into Darcy's equation, differential length of flow line instead of its horizontal projection, as is generally done. Equation for seepage line is given, and diagram for determining the intersection point with downstream face is established. Compared with known solution by Kozeny and Casagrande, considerable differences in the form of seepage line and position of intersection points result. However, differences in the quantity of seepage are small.

V. Mencl, Czechoslovakia

453. Cowan, H. J., Strength of reinforced concrete under the action of combined stresses, and the representation of the criterion of failure by a space model, *Nature* **169,** 4303, p. 663, Apr. 1952.

A brief note which indicates that, in failure (rupture) of reinforced concrete, two types must be distinguished: Crushing due to diagonal shear caused by compression; and cleavage caused by diagonal tension due to shear. The former occurs in the compression zone of bent beams, the latter in members subject to torsion. For combined stresses, a space model (or failure stress surface) is suggested without detailed indications. A number of test results are summarized, obtained on members subject to bending plus torsion in a variety of ratios. Results agree satisfactorily with predictions. George Winter, USA

454. Lossier, H., Pathology of reinforced concrete [La pathologie du béton armé], Paris, Dunod, 1952, 100 pp. 480 Fr. frs.

This is a study of failures of reinforced-concrete structures. Author classifies failures in various categories, explains the reasons for their occurrence and how to prevent similar failures of new structures. Numerous examples of more common failures accompany each chapter.

Failures are divided into three general categories: Those which occur as a result of (a) faulty design of the structure itself, (b) faulty construction, and (c) faulty design of foundations. A major portion of the book is devoted to the design of structures. It is shown that errors either in the choice of the type of structure, in the calculation of the resistance of the structure, or in the design details often lead to failures. It is pointed out that the design calculations are only as good as are the basic assumptions of the theory employed, and the importance of sound engineering judgment is emphasized.

In several shorter chapters, author discusses various problems connected with strengthening and repair of structures, and the steps which should be undertaken in investigations of structural failures. The material is well arranged and, as book presents an important but rather neglected subject, it makes for interesting reading. I. M. Viest, USA

455. McLeod, N. W., Application of triaxial testing to the design of bituminous pavements, "Triaxial testing soils bitum. mixtures," *ASTM Spec. tech. Publ.* no. 106, 79–111, 1951. $3.50.

A rational approach to the design of bituminous paving mixtures utilizing the triaxial compression test is presented. The influence of the rate of deformation employed for the test, on the reported stability values, is reviewed. Data from the test enable an evaluation to be made of the amount of lateral support that bituminous pavements can develop under load in the field. The influence of frictional resistance between pavement and tire and between pavement and base on the stability of bituminous pavements can be determined. It is shown that this factor has a very marked effect on the ability of bituminous pavements to support stationary and moving loads and to resist braking and acceleration forces. The influence of pavement thickness on

pavement stability is indicated. Extensive quantitative information is presented in equations, graphs, and illustrations.

J. Neils Thompson, USA

456. Peltier, R., Study of the mechanical strength of concrete pavements (in French), *Tech. mod. Constr.* **7**, 4, 5; 124–128, 146–151; Apr., May 1952.

A method for the calculation of the strength of concrete slabs on soil is developed mathematically and experimentally, considering the wheel load, the tire pressure, and the moduli of elasticity of the soil and of the concrete. M. W. Jackson, USA

457. Haas, A. M., Research on prestressed-concrete beams (in Dutch), *Ingenieur* **64**, 4, 7; Bt.1–Bt.7, Bt.13–Bt.15; Jan., Feb. 1952.

Article deals only with posttensioned prestressed beams and restricts itself to research on full-size models, i.e., research on the site. Advantages and disadvantages in comparison to laboratory tests are summed up. Author discusses successively research while prestressing, during loading, and the phenomena at the stage of rupture.

In the course of prestressing, the moment can be determined at which the beam will be lifted from the working floor. At that moment the upward movement due to prestressing will be equal to the deflection due to dead load; there is independency from EI. Observations on the jobs agree well with the calculations. The use of a loading platform when testing prestressed-concrete beams is advocated. This makes frequent loading and unloading possible, which is necessary for crack investigation. Elongations were measured with wire dials and Huggenberger dials, with an accuracy of one μ. Measurements were taken on top and bottom flanges. In the neighborhood of the midsection, many dials were placed to prove the validity of Bernoulli's law.

Although the appearance of the first crack satisfactorily checked with the calculations, there is need for a better method for determining cracks without depending on specific values for concrete in tension. Experiments show that a light soft-steel reinforcement is of importance in order to delay and divert cracks.

From measurements of deflection, of elongation, and of curvature and also from test prism, values for the modulus of elasticity were derived. These are compared with the results from formulas giving the relation between the concrete cube strength and the E. Experiment and theory were generally found to be in good agreement. Rupture took place in accordance with the calculations. Phenomena and ultimate strength of different types of prestressed beams (with or without bounded wires) are described.

Finally, a few pictures are given of the jobs where these beams were used, i.e., Schiphol (Amsterdam-Airport) and Emmen (Aku rayon-silk Industries). From author's summary

458. Jacobsohn, W., Dimensioning and cross-section forming of prestressed concrete (in German), *Schweiz. Bauztg.* **70**, 14, 193–198, Apr. 1952.

Author discusses the different equations which occur in connection with prestressed concrete. Combining these equations, author presents a method for calculating the characteristic cross-section values which seems to be convenient. Reference is given to several frequently used types of cross sections, including their economic advantages. C. J. Bernhardt, Norway

459. Trimble, E. G., Determination of continuity bending moments in prestressed continuous beams, Sympos. prestress. concr. stat. indeter. struct., London, Cem. Concr. Assn., 6 pp., 1951.

In author's opinion, the simplest procedure for the calculation of bending moments produced by the act of prestressing is to assume that the joints of the beam are fixed against rotations, to calculate the moments on the two fixed-end beams, and then to apply the Cross method. The paper is mainly devoted to the determination of moments on two fixed-end beams. General relations are derived, and a table is given for prismatic beams with straight horizontal cable and with straight and parabolic haunches. Some suggestions on design criteria for the most suitable position of the tensioned steel are given. All the reasoning of the paper is based on homogeneity; no reference is made to failure. However, when arranging the position of the tensioned steel, failure must be taken into account, and the design ought to cover this state. C. A. Sciammarella, Argentina

460. Cracknell, D. W., and Knight, W. A., The analysis of prestressed concrete statically indeterminate structures, Sympos. prestress. concr. stat. indeter. struct., London, Cem. Concr. Assn., 32 pp., 1951.

Paper gives "... fundamental aspects...statically indeterminate structures, and simple applications of ...methods of analysis..." It is inferred that allowance must be made for axial deformation of prestressed (frame) members whenever this induces moments in contiguous parts of the structure.

"The ultimate strength of prestressed members is discussed in relation to continuity..."

"Examples (include)...a continuous beam, a bridge frame, a multistory frame, and a cylindrical liquid storage tank.

"Appendix gives data for the rapid analysis of structures involving the application of the theory of a beam on an elastic foundation."

From authors' summary by Myle J. Holley, Jr., USA

461. Mackey, S., and Brotton, D. M., An investigation of the behaviour of a riveted plate girder under load, *Struct. Engr.* **30**, 4, 73–81, Apr. 1952.

Load was applied at the third points of a simply supported plate girder of riveted-steel construction. The girder was 20 ft long and 3 ft deep, with a $^3/_{16}$-in. thick web plate. Tests were made at stresses within the elastic stress range with each of five different sets of intermediate stiffeners bolted to the girder. The girder was finally loaded to failure with the smallest of the various sets of stiffeners in place. Ultimate failure was by crippling of the flange following web buckling. Quantities measured included deflection of girder, lateral deflection of web, and strain at several points by means of electrical resistance-wire strain gages.

A fairly complete record of the elastic behavior of the girder was obtained. No significant differences in behavior were noted corresponding to the different sizes of intermediate stiffeners used. This was, apparently, due to the fact that even the smallest stiffeners, consisting of a pair of $3 \times 3 \times {}^1/_4$-in. angles, were considerably larger than necessary to prevent buckling of the stiffeners before the web panels buckled individually.

John W. Clark, USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 381, 424, 475, 485, 515)

462. Bridgman, P. W., Studies in large plastic flow and fracture with special emphasis on the effects of hydrostatic pressure, New York, London, McGraw-Hill Book Co., Inc., 1952. x + 362 pp. $8.

Book concerns the changes in the mechanical behavior of solids that occur when high hydrostatic pressures are superposed on the external forces under which they are stressed. The ways in which solids and, particularly, the ductile metals deform and

break under these conditions are described, and the interesting mechanical phenomena associated with high hydrostatic pressures summarized. Since these are of great interest to engineers, it seems perhaps appropriate to consider the book from the viewpoint of the mechanical engineer in these following remarks, which are written for a journal published mainly for the engineering profession.

The book is divided in four parts: Tests under hydrostatic pressure (covering such topics as the tension of steel and other materials under pressure, two-dimensional tension under pressure, collapse of hollow cylinders of steel, etc.); other tests involving large deformations (simple, two-dimensional, mixed compression, torsion combined with simple compression); plastic flow and fracture after prestraining and general survey. Author mentions that his work "had its origin and motivation in the discovery, shortly before the outbreak of the war, that ordinary steels increase enormously in ductility while exposed to hydrostatic pressures in the range between 300,000 and 450,000 psi." (p. 1); that it had been found in other armor-piercing tests that the stresses around the nose of projectiles in the process of penetration were in that same range, and that here was a factor which had been little considered formerly, namely, the increase of the ductility of strong steels stressed in tension with superposed high hydrostatic pressures. In his own tests, he found in small tensile bars of steel under these conditions that they would contract much more before they broke than under ordinary testing conditions. From the good engineering experiences which were available at that time and long before it, much of this was known and could have been expected for the strong steels also, remembering that otherwise much weaker and *brittle* marble cylinders had been deformed permanently in axial tension or compression (tests by von Kármán, 1911, and R. Böker, 1914, and by others) by squeezing them under superposed hydrostatic pressures, requiring for the initiation of the plastic distortion ("ductility") fluid pressures of the moderate order of magnitude of only 300 to 3000 atm (kg/cm²), in contrast to the inconveniently high fluid pressures of 21,000 to 32,000 atm necessary in the similar tests of the author on strong alloy steels. The beneficial effects of lateral pressures combined with tensile stresses in reducing the forces were generally applied in the forming processes (hot and cold rolling, etc.) and utilized by the engineering profession. Similar remarks may refer to certain fractures "of an unanticipated nature" which author quotes from his early observations, in which he saw in his pressure cylinders the cracks on the outside surface "contrary to expectations based on engineering experience in a lower range of stress"; but engineers have predicted in their calculations of the stresses in heavy-walled cylinders exposed to internal pressure that the cylinders may carry the greatest tensile stresses in the tangential direction at the *outer* surface after the plastic state has gradually developed. Whether the greatest tensile stress is generated at the inner or at the outer surface of the cylinder depends on the form of the general strain-hardening function of the metal. Thus, not the engineering experience was so much at fault, but maybe the physicist's when he anticipated his stresses in formulas based on the theory of elasticity. Author devotes some space and thoughts to explaining the fractures in brittle materials (glasses), the "pinching-off effect" in small cylinders carrying high pressure on their lateral surface, admitting that it is due to secondary circumstances to which it was attributed by various investigators. Whereas the author's pervasive thoughts in advocating and in attempting to advance mechanical explanations for a number of these phenomena of flow and fracture and in analyzing a few of them by the means of mechanics deserve to be commended, it may, perhaps, be said that in many of these tests the range of certain variables was greatly exaggerated beyond the limits within which these have or still retain significant values in practical engineering applications; also, that engineers are well aware of some of these practical limits (for example, of too much successively applied cold work causing an undesirable deterioration of the crystalline structure of a ductile metal). The book leaves the impression that certain general defects in the way many experimental investigations were made during the last war, or reported for certain government agencies, were carried over into this present monograph. The book appears overloaded to a certain degree with details describing experimental techniques; also with long, numerical tables of empirical information. It would have been far more valuable for the prospective younger readers of this book if the author had conceded to take issue of work of a related nature which has been done during the past 10–20 years abroad (in Austria, England, Germany, and Switzerland) and in this country on the flow of solids and the conditions of fracture under combined stress, to which the references seem unusually scarce in a monograph of this type. While the mathematical theory of plasticity, for example, served the author most advantageously throughout his entire book in his mechanical considerations and the terminology derived from it, he gave to it in the last, the 24th chapter, the more capriciously sounding new name, "gathering up the threads," in what appears more or less a condensed version of it, having, incidentally, one single footnote and one additional reference to a name in 17 pages of text. A. Nadai, USA

463. Cooper, W. E., Determination of principal plastic strains, *Trans. ASME* **74,** 5, 821–824, July 1952.

See AMR **5,** Rev. 1737.

464. Il'yushin, A. A., Plasticity. Part one. Elastic-plastic deformations [Plastichnost'. Chast' pervaya. Uprugo-plasticheskiye deformatsii], Moscow-Leningrad, OGIZ, 1948, 376 pp.

Book is based on work in the laboratory for investigation of materials at the University of Moscow. First chapter deals with the fundamental laws of elastoplastic deformation. The plastic properties are first explained for the one-dimensional state of stress with tensile force or pressure (nonlinear relation between stress and strain, the logarithmic influence of the rate of strain on stress, strain hardening, effect of Bauschinger, elastic aftereffect). Then the state of stress is described by the stress tensor, and the elementary properties of this tensor are explained in usual way. The deviator-tensor (D_s) is introduced, its intensity τ_i defined by the root of its scalar product by itself and used for the formulation of the yield conditions of Coulomb and Huber-Mises. For small deformation, the tensor of strain (E), its deviator (D_e), intensity γ_i, and corresponding guiding tensor [see also Fromm, *Ing.-Arch.* **4,** 432, 1933] ($\overline{D}_e$) defined by $(D_e)/\gamma_i$. Then the law of Hooke is written in the simple form: $(\overline{D}_s) = (\overline{D}_e)$, $\sigma = 3Ke$, $\tau_i = g\gamma_i$, where σ and e are the spherical parts of stress and strain tensor. The corresponding yield conditions are discussed as well as the experiments of Nadai-Lode, Roš and Eichinger, Taylor and Quinney, Schmidt, Davis. The following theories of plasticity are considered: Saint Venant-Levy-von Mises, Prandtl-Reuss, Hencky-Nadai, Prager.

In the second chapter, on the fundamental equations of the theory of small elastoplastic deformations (in the case of deformation with increasing intensity denoted as "active"; in the case of decreasing intensity denoted as "passive"), the medium is supposed incompressible; the guiding tensors of deformation and stress are identical, and the intensity of stress is a well-defined function of the intensity of deformation. The work done, the variational principle and the conditions of equilibrium are given.

In the third chapter, the simpler problems of the theory of

plasticity are considered—bending of beams, the buckling of rods, roller, hollow bullet under the influence of internal and external pressure, and thick tubes. The fourth chapter considers the equilibrium of plates and shells (plane state of stress, the inner forces, moment and deformation of shells and the problem of strength, deformation of plates in their own plane, bending of plates, approximation method for the bending of plates, strength of plates, momentless deformation of shells with revolution symmetry, symmetrical deformation of cylindrical shells, strength of cylindrical shells).

Chapter 5 concerns buckling of plates and shells (forces and moments by deformation of the middle surface in case of buckling, buckling of plates and an approximation for it, buckling of cylindrical shells, the conditions in the experiments with mild steel of Kármán). In chapter 6 are considered the pressure of punches on incompressible plastic media (plain deformation of ideal plastic media, plain punch, punches symmetrical to the axis). Chapter 7 includes dynamical problems of plasticity (propagation of plain nonlinear waves, the elastoplastic waves of Rakhmatulin, propagation of waves originated by transversal impact on a flexible thread, polar-symmetric problem). A bibliography of 87 items (43 of them by Russian authors) lists the literature specified for each chapter. H. Schlechtweg, Germany

465. Kondo, K., A new theory concerning the yielding of materials based on Riemannian geometry, *Japan sci. Rev.* **1,** 3, 7–9, Sept. 1950.

A critical study of the natures of incompatibility and dislocation of elastic bodies, based on Riemannian geometry, leads to a new theory and analytical expressions concerning the yielding of the materials, such as mild steel which shows a clear yield point. Examples of the most important typical conditions of load are analyzed. The results obtained are in conformation with the experimental facts. From author's summary

466. Umstätter, H., Rheological considerations of creep of steel (in German), *Arch. Eisenhüttenw.* **23,** 34, 119–126, Mar./Apr. 1952.

First part introduces metallurgists to rheological concepts, especially Maxwell-body [see AMR **4,** Revs. 1158, 1159] connecting viscosity with elasticity through relaxation. Second part refers to illustrative experiments—tension, compression, notched bar impact—on elastic bitumen purporting to show analogy with behavior of steel (not adequately, reviewer believes). Third part describes valuable novel arrangement for determination of creep in metals. Wire fixed in tension within steel cylinder kept at constant temperature is excited by electromagnets to vibrations, which are compared with standard vibrations by registering both on the oscillograph. With exact equal frequencies, a stationary Lissajous curve results, which, however, starts to rotate as soon as relaxations set in. By measuring angular velocity of rotation, differences of frequencies can be determined from which relaxation velocity can be calculated. Alternatively, figure can be kept stationary by continuously lengthening wire. Assuming a power-law dependence of creep gradient vs. time, relaxation is expressed by means of Γ function introduced into rheology by Scott Blair [*Proc. roy. Soc. Lond.* (*A*) **189,** 69–87, 1947].

M. Reiner, Israel

467. Trotter, J., Electron-microscopic studies of slip in aluminum during creep, *J. Inst. Metals* **80,** 521–523, 1951–1952.

Tensile specimen of 99.98% Al, when slowly deformed at 200 C, showed intimate segments of primary and cross slip, not bundles of long parallel slip lamellae as found in room temperature deformation by Heidenreich and Shockley. While these results could be influenced by a surface oxide film, somewhat thicker then normal, the regularity of the fine structure of the slip makes it probable that they possess distinct physical significance with respect to deformation at elevated temperatures.

H. F. Winterkorn, USA

468. Puttick, K. E., and King, R., Boundary slip in bicrystals of tin, *J. Inst. Metals* **80,** 537–544, 1951/1952.

Bicrystals of tin were prepared with quite straight boundaries and subjected to simple shear at various temperatures. The relative displacement of points on opposite sides of the boundary was measured by observing microscopically the motion of fine scratches initially perpendicular to the boundary.

Three general types of displacement-time curves were observed. The most common consisted of an initially straight part, followed by a part with decreasing slope (Type A). Sometimes there was a short initial portion of decreasing slope preceding the straight part (Type B). In some cases, the straight portion was followed by alternate periods of increasing and decreasing slopes, but with a decreasing slope on the average (Type C). The slope of the initially straight, or presently straight portion of the displacement-time curve was linear with stress for all temperatures, and the slopes of the displacement rate $\dot{\delta}$ vs. stress σ curve varied linearly with the reciprocal temperature T. Thus

$$\dot{\delta} = 10^{-4}\sigma e^{-19000/TR}$$

Usually the grain boundary remains stationary and the scribed line suffers a simple offset, but sometimes the boundary migrated laterally and the scratch became distorted near the boundary. Occasionally, the appearance of a polyganized substructure near the boundary indicated that some distortion had occurred in the neighborhood of the boundary.

The grain boundary was found to be corrugated when opened up by intercrystalline attack by mercury. The corrugations can be removed by straining followed by annealing, but not by annealing alone.

The above equation for initial displacement rate is similar in form to that observed by Kê in torsion pendulum experiments, but the initial rate was 100,000 times smaller. This suggests that there was an initial steep portion at the beginning of the A-type curves similar to that observed on the B-type curves, but within a displacement range too small to measure microscopically. This initially rapid rate may correspond to that measured by Kê.

A reasonable explanation for the shapes of the various types of displacement-time curves was given in terms of viscous shearing, boundary migration, and distortions of the crystal that would be necessary to allow shearing-off of the grain-boundary corrugations. J. D. Lubahn, USA

469. Briscoe, P. A., Dunning, W. J., and Seymour, R. C., The rheology of plastic dispersions, *Brit. J. appl. phys.* **3,** 6, 193–196, June 1952.

While authors' contention "that Bingham plasticity can be considered as derived by continuous modification from a Newtonian liquid" may be conjectural, the experimental facts of this paper seem to be these: A puttylike material was prepared of 78% by volume of powdered solid and 22% by volume of soft mineral jelly. Cylinders (15-mm diam) of this material were examined in a plastometer where the height of the cylinders under a load was measured at 10-sec intervals for 10 min. Compression-time curves of the type $-dt/dh = kt + a$ were obtained over a range of loads from 50 g-wt to 200 g-wt (disregarding fluctuations between 0.078 and 0.111 in the value of k). The amount of compression after 10 min depends only upon the compressing weight (proportionality factor c). On passing the putty-

like material several times through a rolling mill and taking a sample after each passage, it was found that k showed a minimum and c a maximum near the fifth and sixth millings. The product $k \cdot c$ is approximately constant. Authors state that "subjective evaluation by various persons, who moulded and worked the samples in their hands, indicated that the 'most plastic' sample was either the fifth or sixth." Change of particle-size distribution on milling was determined, and microscopic examination showed the particles to be roughly spherical.

R. Schnurmann, England

470. Fromm, H., The relaxation correction in capillary-viscosimetry (in German), *Kolloid Z.* **126,** 2/3, 72–77, May 1952.

In the first part of this paper, general approaches to fundamental problems of rheology are discussed. Distinction between material property and characteristic quantity (Kennwert) are carefully introduced. Definitions of Newtonian and Maxwellian fluids are given, and the electric analogy of the Maxwell law is analyzed in view of author's previous results in connection with evaluation of Couette-viscosimeter experiments [AMR 5, Rev. 3096].

The second part contains the derivation of a formula for the relaxation correction of a Maxwellian fluid and shows the effect of relaxation time on the measured viscosity value in a capillary viscosimeter. The elementary derivation is based on the energy equation, and the result contains height, compression, kinetic energy, dissipation, and relaxation corrections. The dimensionless relaxation correction is $Tv/3l$ (T relaxation time, v velocity, l length of pipe), so it is significant for short pipes and high velocities. Reviewer notes that for such conditions the uncertainty of some of the afore-mentioned corrections might make author's result interesting only from a theoretical point of view. No experimental results are presented in paper.

V. G. Szebehely, USA

471. Hall, E. O., The deformation of low-carbon steel in the blue-brittle range, *J. Iron Steel Inst.* **170,** part 4, 331–336, Apr. 1952.

A study was made of the deformation of Bessemer and Armco iron wires and thin strip at temperatures in the region 150–250 C, and comparison made with behavior at room temperature. Wires were 1-mm diam, and strip $2 \times {}^1/_2$ mm in cross section. Two types of plastic deformation occurred during the tests: (a) Lüder's extension resulting in saw-tooth stress variation of remarkable regularity in tests at 205 C; and (b) sudden small random drops in the load due to secondary deformation bands after aging had occurred. It is shown that the jagged stress-strain curves arise from interrupted propagation of the Lüder's bands which suddenly dart forward but soon become blocked. At high strain rates, the type (a) stress fluctuations were entirely suppressed. The type (a) fluctuation also depends on temperature, and the size of the stress fluctuation was smaller as the grain size of the specimen increased. The importance of the use of thin strip and wire in investigating these localized deformation bands in mild steel is emphasized. All data were autographically recorded by means of special stress-measuring system and optical lever magnification.

T. J. Dolan, USA

472. Ferry, J. D., Fitzgerald, E. R., Grandine, L. D., Jr., and Williams, M. L., Temperature dependence of dynamic properties of elastomers; relaxation distributions, *Indust. Engng. Chem.* **44,** 4, 703–706, Apr. 1952.

A method is given for calculating the distribution function of relaxation times from dynamic mechanical data. Once the distribution function has been determined, it is possible to calculate such quantities as viscosity, elastic energy stored during deformation, elastic recovery, and stress relaxation. A method of reduced variables is described by which the temperature and frequency dependence of dynamic mechanical properties can be interrelated. Elastic moduli or viscosity obtained over a wide range of temperature and frequency can be reduced to a single composite curve when plotted against the reduced frequency. The methods are illustrated by data for a polyisobutylene rubber.

Lawrence Nielsen, USA

473. Raineri, G., Viscous solids subjected to distorsion varying arbitrarily with time (in Italian), *Atti Accad. Sci. Torino I. Cl. Sci. Fis. Mat. Nat.* **85,** 236–245, 1950–1951.

The author claims to prove for what he calls a viscous solid, "the independence of the final deformation from the manner in which the distorsion is varied in time." The reviewer is unable to understand the terms used or to follow the analysis.

C. Truesdell, USA

Failure, Mechanics of Solid State

(See also Revs. 453, 462, 488, 493)

474. Vedeler, G., Brittle fracture in mild steel, *K. norske Vidensk. Selsk. Förh.* **22, 23;** 7, 16; 21–27, 58–61; 1949, 1951.

475. Pavlov, V. A., and Yakutovich, M. V., Nature of "ductile" failure (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **77,** 1, 49–50, Mar. 1951.

Authors observed formation and growth of microcracks in plexiglas plates under tension, with stress concentrated by artificial neck or by holes. Three microphotographs are shown. Cracks form predominantly in regions of high shear stress but are oriented with their surfaces perpendicular to the local tension. Authors interpret results as supporting the view that fracture by shear and by cleavage are not essentially different processes, but that in the former the distortion of the lattice by plastic flow makes microcrack formation possible at a lower tension.

William Fuller Brown, Jr., USA

476. Pavlov, V. A., Formation of microscopic crack in aluminum during plastic deformation (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **78,** 4, 677–679, June 1951.

Author observed formation of microcracks at polished surface of aluminum plates under tension. Two microphotographs are shown. Cracks form predominantly along slip planes; those first formed are oriented with their surfaces perpendicular to the tension. As strain increases, cracks already formed rotate, and new ones form in other orientations; their shapes, too, change. Author interprets these results qualitatively by considering the local stress field near a crack. He regards them as supporting the analysis of the shear fracture process advanced previously (see preceding review).

William Fuller Brown, Jr., USA

477. Forsyth, P. J. E., Some metallographic observations on the fatigue of metals, *J. Inst. Metals* **80,** 181–186, 1951/1952.

A metallographic investigation of the effects of cyclic stresses on the microstructure of an aluminum-${}^1/_2\%$-silver alloy has shown that factors other than simple slip are involved in the mechanism of fatigue at room temperature.

There is evidence of a recovery process associated with the formation of deformation bands and crystallites during fatiguing of the metal, and it is suggested that the observed anomalies in the effect of stress concentration on crack progress are the result of crystallite formation at the roots of the cracks.

From author's summary by W. J. Anderson, USA

478. Orowan, E., Stress concentrations in steel under cyclic load, *Weld. Res. Suppl.* **17,** 6, 273s–282s, June 1952.

Paper discusses the behavior of stress concentrations in ductile bodies under cyclic load, with particular reference to steel pressure vessels. Steels in common use are ductile enough to withstand some plastic deformation at stress peaks if the load is applied only once. Whether or not failure will result from repeated loading cannot be determined from conventional fatigue data because the amplitudes of stress and strain do not remain constant at points of local yielding. Part I of the paper deals with these changes and presents a simple graphical solution. Part II deals with stresses greater than the endurance limit and which might be safe for a limited number of load applications. Part III deals with the practical possibilities of increasing the endurance of pressure vessels. Marshall Holt, USA

479. Meyersberg, G., Size and surface effect on the strength of materials (in German), *Trans. roy. Inst. Technol. Stockholm* no. 58, 123 pp., 1952.

The wealth of information accumulated on the subject of size and surface effects since their importance was discovered is scattered in a number of papers dealing with various particular aspects. The present paper should be welcomed as an attempt to synthesize and organize the knowledge of these effects.

A critical survey of the theories of A. A. Griffith and W. Weibull introduces the paper. Accepting the statical theory of Weibull, author develops it further and introdues a factor m, called "sensitivity factor." The value of m is a function of the stress state as well as a material constant. For uniform tension, it is essentially a material constant and reflects the nature, number, and distributions of the flaws in the material. It can be determined experimentally by the test of specimens of various volume, as the slope of the logarithmic plot of the breaking stress against volume. Corrections are shown in order to apply the values of standardized tests to various loading conditions.

The scatter of the experimental points around the average line leads to simple equations for the determination of the distribution curves, the last ones representing the probabilities of failure as a function of the stress level.

The whole discussion of the size effect rests primarily with the brittle materials like cast iron. Author assumes that the same way of thinking could also apply to the investigation of the initiation of the yielding in ductile metals. A more elaborate discussion of this point would be desirable.

As the volume of the considered specimens decreases, size effect loses importance and surface effect becomes the one directing the process of failure.

Discussing surface effect, author rejects Oberhofer's and Poengsen's theory of the lack of quasi-isotropy, and attributes more importance to the microstructural properties of the surface layer. The influence of these properties becomes proportionally greater as the total volume of the specimen decreases. The initiation and propagation of cracks in the surface layer are basically different from those in the core. The crack initiates in this layer at a low stress level, when the damping effect of the adjacent sound parts of the material is considerable. In the case of cast iron, this reflects in the lack of the otherwise usual load report following the fracture. Finding a close analogy between these types of failure and fatigue failures, author suggests the use of the term *creep* for all failures initiated in a surface layer.

Extensive tests of cast-iron specimens are presented in the 4th chapter. Bending and torsion tests on square and round bars cut from a cast block were performed. The author suggests the use of the Ludwik-Krystoff wedge-compression test as a substitute for tensile tests. In reviewer's opinion, the last one does not seem to be a fortunate choice, and preference should be given to the simple tensile test. The experiments, however, showed good relation with the theoretical assumptions.

The mathematical treatment of the subject is clear, and a great number of appendixes and tables make it easy to follow and to apply. Extensive literature references are given.

D. Vasarhelyi, USA

480. Petch, N. J., and Stables, P., Delayed fracture of metals under static load, *Nature* **169,** 4307, 842–843, May 1952.

Authors propose that metals fail in a manner similar to failure of glass from gas absorption on Griffith crack surface. Theory is that brittle strength of iron is lowered by the hydrogen uniformly distributed in solution; but small quantity necessary suggests some concentration mechanism is operative. Theory predicts a time delay necessary for development of embrittlement.

Test results are reported on fracture of both hydrogenated and hydrogen-free iron by (a) impact and (b) slower test in testing machine. Results confirm theory, showing a delay such that no embrittlement is detected at rapid rate of loading.

D. E. Hardenbergh, USA

Material Test Techniques

(See also Revs. 466, 508, 510)

481. Findley, W. N., Jones, P. G., Mitchell, W. I., and Sutherland, R. L., Fatigue machines for low temperatures and for miniature specimens, *Bull. ASTM* no. 184, 53–55, Sept. 1952.

A description of two fatigue machines capable of testing small specimens in fatigue at temperatures as low as −320 F; one machine designed for rotating-bending, the other capable of testing cantilever specimens in flexural, torsional, or combined flexural-torsional stress states. A third, consisting of a Krouse plate-bending fatigue machine modified to take miniature specimens (full size $^3/_4$ in. long × $^3/_{16}$-in. diam with a working section $^3/_{32}$-in. diam and approximately $^5/_8$ in. long) is also described.

E. E. Sechler, USA

482. Savornin, J., and Renucci, G., Measurement of Young's modulus of metallic rods by an electromagnetic method (in French), *C. R. Acad. Sci. Paris* **234,** 21, 2045–2046, May 1952.

Test bar is excited into longitudinal vibrations at one end, and transducer senses vibrations at other end, while middle is supported on soft rubber ring. Oscilloscope indicates resonant frequency. Conventional formulas are then used to calculate modulus. A. Yorgiadis, USA

483. Benson, F. J., Appraisal of several methods of testing asphaltic concrete, *Tex. Engng. Exp. Sta. Bull.* 126, 81 pp., June 1952.

484. Andersen, J., and Nerenst, P., Wave velocity in concrete, *J. Amer. Concr. Inst.* **23,** 8, 613–635, Apr. 1952.

Wave velocity is a parameter indicating the quality of concrete, which can be determined nondestructively. The velocity is established by means of two crystal gramophone pickups, their needles resting on the surface of the specimen a distinct distance apart. After a shock wave has been generated by a hammer blow, a condensor-type chronograph measures the time needed for the wave to travel from one pickup to the other. Method has been used to study the hardening process of concrete specimens. A number of practical investigations are described and discussed, such as the study of concrete structures damaged by fire, early

freezing, etc. A detailed description of the apparatus used and the theoretical considerations is included.

R. G. Boiten, Holland

Mechanical Properties of Specific Materials

(See also Revs. 385, 397, 399, 455, 466, 467, 468, 471, 472, 476, 484, 513, 652)

485. **Chang, H. C., and Grant, N. J., Observations of creep of the grain boundary in high purity aluminum,** *J. Metals* **4,** 6, 619–625, June 1952.

Creep properties of individual grain boundaries are investigated by measuring distance of reference marks on both sides of boundaries of coarse-grained strips, produced by pressing a thin sewing needle. Testing temperature was 700 F (370 C), stress 85 psi (60g/mm²); micrographs were taken after cooling to room temperature under load, and some observations during creep were made with high temperature microscope. Results: Deformation occurs by alternating boundary gliding and migration, and is also indicated in creep curve drawn from reference marks obtained in steps with high and low rate, respectively. Migration is strongly influenced by surface faults (etch pits, etc.), mainly as attracting effect. Gliding causes two types of deformation in the grains: fold and subgrain formation; for both, lattice bending is believed to play an important role. Gliding is not restricted to thin layers, but includes a rather large volume. In reviewer's opinion, grain boundaries may, nevertheless, form few atomic layers before creeping. A. Kochendörfer, Germany

486. **Slifkin, L., and Kauzmann, W., The creep of zinc single crystals,** *J. appl. Phys.* **23,** 7, 746–753, July 1952.

Transient creep of very pure zinc single crystals, prepared by Bridgman's method, has been studied at 35 C using a modified Marten's extensometer. Strain rates were about 10^{-5}/min. Results are in accordance with Andrade's law, $\gamma = \gamma_0 + \beta \cdot t^{1/3}$, except that values of exponent scatter about $^1/_3$ outside range of experimental error. The instantaneous plastic strain γ_0 when applying load, has been found proportional to β. Further results are the detection of a short but rapid stage of recovery and the observation of a contraction with time when removing the load (single crystals of extreme purity!). The latter effect has been predicted by piling-up theory of like-sign dislocations.

Franz Wever, Germany

487. **Sakui, S., Satō, Y., Ōkawa, C., and Satō, K., Impact tensile test of single crystal of metal. I** (in Japanese), *Rep. sci. Res. Inst.* **27,** 4, 309–315, 1951.

The tests were conducted by the authors principally on single aluminum crystals to study the mechanism of deformation, since they believed that polycrystalline specimens would exhibit less noticeable changes. The fractured specimens were studied for grain orientation, recrystallized grain numbers, deformation angles, slip lines, asterisms in Laue patterns, and time-load relationship, as well as the relationships between the ultimate static and dynamic stresses and strains at failure. The latter relationships were determined also for polycrystalline specimens.

Albert Yamamoto, USA

488. **Epremian, E., and Mehl, R. F., Investigation of statistical nature of fatigue properties,** *NACA TN* 2719, 119 pp., June 1952.

The statistical nature of fatigue life and endurance limit of rotating beam and vibrating cantilever specimens of SAE 1050 steel, SAE 4340 steel, and Armco are investigated on the basis of the assumption that the distribution function of fatigue life is logarithmic-normal, and that the mortality curve for "endurance" can be dealt with by probit-analysis, which is equivalent to the assumption of a normal distribution of the mortality of specimens around the $P = 0.5$ or median "endurance limit." Test results indicate an increase of the dispersion of the fatigue-life distribution with decreasing stress level for both types of tests, and suggest that the dispersion can be related to the number of imperfections and inclusion present within the metal.

A. M. Freudenthal, USA

489. **Templin, R. L., Howell, F. M., Lyst, J. O., Fatigue properties of cast aluminum alloys,** *Prod. Engng.* **23,** 5, 119–123, May 1952.

The results of about 2000 rotating-beam-fatigue tests are given for specimens taken from 28 aluminum alloys cast in sand and from 17 alloys cast in permanent molds. The alloys covered a wide range of chemical composition and of heat treatment; the tensile strengths ranged from 17,600 to 52,000 psi. Tests were made on smooth specimens and on specimens with a 60° sharp V notch. The fatigue data for all the notched specimens fell into a common S-N scatter band regardless of composition and heat treatment. Comparison with the scatter bands for the smooth specimens showed an average reduction in fatigue strength, due to the notch, of about 25% for the sand-cast alloys and of about 35% for the permanent mold-cast alloys. A smaller number of fatigue tests at elevated temperatures on smooth cantilever beam specimens indicated a reduction in fatigue strength of the order of 40% at a temperature of 600 F as compared to the room-temperature values. Walter Ramberg, USA

490. **Shackell, K. K., and Welsh, J. H., Plastic flexure of mild steel beams of rectangular cross-section,** *Instn. mech. Engrs. Proc.* (*A*) **166,** 1, 112–119, 1952.

The object of tension, compression, and flexure tests on 0.28% carbon steel was to investigate the shape of the stress-strain curve immediately after the initial yielding. The results indicate that the stress-strain curve falls rapidly but not immediately from the upper to the lower yield value, and that a beam is capable of withstanding a slightly greater bending moment than would be predicted by calculations based on the direct stress tests, including the upper yield stress.

From authors' summary by Minglung Pei, USA

491. **Freeman, J. W., Comstock, G. F., and White, A. E., Rupture and creep characteristics of titanium-stabilized stainless steel at 1100 to 1300 F,** *Trans. ASME* **74,** 5, 793–801, July 1952.

See AMR **5,** Rev. 1421.

492. **Lemoine, J. A., and Sariban, A., Contribution to the study of aging of mild steel** (in French), *Rev. Soudure* **8,** 2, 84–104, 1952.

Authors review thoroughly the fundamentals of aging due to cold-working and heat-treating, noting effects of various elements. Experimental results are discussed in second part. Indexes of aging used are Vickers hardness impact resistance, and bend test of microspecimens. Latter test was described by Mironott, N. [*Ossature métall.* no. 3/4, 1945]. Bend test was used on specimens cut from tapered or stepped tensile piece immediately after fracture. One of two specimens cut from any given zone was tested without aging; other, after artificial aging. Linear relationship between degree of cold work and both hardness and bending index was found for steels investigated. No uniform relationship for aging due to heat treatment was obtained.

F. J. Mehringer, USA

493. Isibasi, T., Effects of notches on fatigue strength of gray cast iron, *Mem. Fac. Engng. Kyushu Univ.* **13,** 1, 71–86, 1952.

Hollow cylindrical specimens with outside diameters of 12 or 23 mm were tested in rotating beam machines with transverse holes whose diameters varied from 0.05 to 0.48 of the specimen diameter. The strength-reduction factor due to the notch was nearly unity as long as the diameter of the hole was small compared with the specimen diameter. The strength reduction increased with increased size of specimen and greater diameter of circle. Author proposes an explanation for this size effect based on the presence of graphite flakes acting as stress raisers superposed on the localized stress at the hole. By using the stress at the root of the graphite flake and an empirical formula, he shows good agreement between observed and computed values for strength reduction.

T. J. Dolan, USA

494. Éidel'man, S. Ya., Determination of elastic characteristics and creep of concrete in structures (in Russian), *Gidrotekh. Stroit,* no. 5, 12–16, 1952.

Gradual development of stresses in massive concrete structures is studied by means of embedded strain meters. The total strain is made up of three parts—elastic strain; creep strain, proportional to the elastic strain and increasing with time; and free volumetric strain caused by temperature and shrinkage. Author proposes to measure the two latter parts of strain on control cylinders, built into the structure, and isolated from it all around except on one end. These control cylinders are either left unstressed or are loaded with a contant load applied hydraulically at the free end. The elastic strain, separated from the other two parts, is converted into stress by means of modulus of elasticity found from similar control cylinders.

Author seems to overlook the fact that the ratio of the creep and elastic stresses would be different in control cylinders and in the structure due to variation of stress in the latter. Questionable also is the assumption of the zero value of the coefficient of lateral creep.

A. Hrennikoff, Canada

495. Effect of vibration on air content of mass concrete, *Wwys. Exp. Sta. tech. Memo.* 6-345, 14 pp., 3 tables, May 1952. $0.50.

Tests were made to observe the effect of high-frequency (13,000 vpm) and moderate-frequency (6800 vpm) vibration on concrete ranging from dry to wet consistency, containing 6-in. coarse aggregate, and having nominal air contents of 3, 6, and 9% in that portion of the mix smaller than $1^1/_2$ in. Cores drilled from hardened specimens of the concrete with 6% air content were examined micrometrically for amount and distribution of air and coarse aggregate.

The high-frequency vibrator was found to cause more rapid loss of entrained air than the moderate-frequency vibrator. However, either vibrator could cause a 50% loss in air from nominal 3% air-content concrete in 30 seconds. The rate at which air was lost generally increased with slump, but not to a marked degree. The high-frequency vibrator had more effect in causing movement (escape) of air, while the moderate-frequency vibrator caused more movement (segregation) of the coarse aggregate.

From authors' summary

496. Sweet, H. S., Variation in density of lightweight concrete aggregates, *Bull. ASTM* no. 184, 44–47, Sept. 1952.

Tests of specific gravity, absorption, and concrete properties of different gradations of lightweight aggregates were performed. This paper describes the influence of the variation in specific gravity for different particle sizes on the problem of specifying sieve analysis limits on a weight basis, and on the design of concrete mixes for workability. It is concluded that certain modifications should be made in the grading specification for lightweight aggregates.

From author's summary

497. Williams, E. J., Applications of component analysis to the study of properties of timber, *Austral. J. appl. Sci.,* **3,** 2, 101–118, June 1952.

Paper describes how the different components of variability in properties of timber may be distinguished and their magnitude assessed. The variation that occurs between different trees can be separated from that occurring within the tree, and the variation between species can be separated from that occurring between different trees of the same species. The need is indicated for this type of analysis in arriving at valid standard errors for averages, etc., of properties, as well as in making significance tests of differences among experimental results. Component analysis is important also as a guide to sampling, and methods of improving the efficiency of sampling by its use are described.

From author's summary

498. Maron, S. H., Madow, B. P., and Trinastic, J. C., Ultimate and actual tensile strengths of latex films, *Indust. Engng. Chem.* **44,** 7, 1633–1634, July 1952.

499. Gordon, J. E., On the present and potential efficiency of structural plastics, *J. roy. aero. Soc.* **56,** 501, 704–728, Sept. 1952.

Structural plastics (fibrous materials impregnated with plastics) are examined mathematically to see if improvements can be made in their strength and stiffness properties. If substantial improvements could be made, structural plastics would replace metals in many applications where weight is an important factor. At present the best materials are asbestos fibers impregnated with a phenol formaldehyde resin, or glass fibers impregnated with a polyester resin.

The mechanical properties of such materials depend primarily upon the arrangement of the fibers, while the resin serves only as a glue. Calculations are made for various types of fiber arrangements. Arrangement of the fibers in a random three-dimensional network is inefficient, while the use of parallel bands of fibers arranged in the form of an X orientation is most efficient. Other arrangements of fibers are also discussed.

It is suggested that still greater improvements might be achieved by using materials in the form of plates, such as mica or alumina, instead of fibers.

L. Nielsen, USA

500. Wright, E. E., Stress relaxation in plastics and insulating materials, *Bull. ASTM* no. 184, 47–49, Sept. 1952.

This paper describes a constant-deflection procedure for direct measurement of stress relaxation or change thereof, thereby permitting evaluation in terms of a material's ability to maintain a tight assembly under conditions simulating actual use. Apparatus for carrying out the test is described, and typical data illustrating its usefulness are included.

From author's summary

501. Bobeth, W., Study of tensile impact tests of textiles (in German), *Faserforsch. Textiltech.* **2,** 2, 51–58, Feb. 1951.

Early high-speed rupture tests of ropes, cords, and threads by tensile impact are reviewed, and a description is given of the machine used by author for similar tests. A small number of tests are reported for ropes made of common materials, but no attempt is made to compare materials in a fundamental way. The test favored by author is one in which a projection on a revolving

flywheel strikes an arm holding one end of the specimen. Loss of energy of the wheel during the blow is used as a measure of impact strength of the rope. A larger testing machine is to be built, using experience gained with the present machine.

W. C. Johnson, Jr., USA

502. Hoerner, S. F., Aerodynamic properties of screens and fabrics, *Textile Res. J.*, **22,** 4, 274–280, Apr. 1952.

General rules are derived from available test data for the pressure loss of flow across wire screens and simple fabrics. Author is an expert in the field of aerodynamic drag, and he relates the concept of permeability of cloth to establish principles of fluid dynamics. The main variables considered are air speed, per cent projected solid area, and Reynolds number based on filament diameter. At very low air speed (and Reynolds number), pressure losses seem to be viscous and proportional to the velocity; at high air speeds, the losses seem to be due to sudden expansion of air-flow area behind the openings of the screen. In the intermediate range, a formula for loss coefficient has been worked out in terms of Reynolds number and the solidity ratio of the material. Discussion is given of pressure loss at air speeds comparable with the speed of sound, but these require pressures of approximately 100 in. of water for ordinary fabrics. Paper does not consider the complications of different weaves and materials, but it does give an understanding of the principles involved in measuring and specifying the permeability of materials. Author recommends use of dynamic pressure of flow, divided by pressure loss, as a nondimensional parameter to indicate the permeability of cloths and other materials. Incidentally, equation 19 is in error and needs to be revised to agree with equation 18.

W. C. Johnson, Jr., USA

503. Sen, K. R., An instrument for measuring the hardness of bast fibres, *J. sci. indust. Res. India* **11,** 6, 221–225, June 1952.

The construction and operation of an instrument for measuring the hardness of jute fibers are described. The hardness indexes of Tossa and White jute filaments have been determined, and the nature of measurements which can be made with the help of the new instrument has been discussed. The instrument can be used for measuring the hardness of other bast fibers.

From author's summary

504. Natus, D., A photoelectric uniformity tester for running yarn, thread, and the like (in German), *Faserforsch. Textiltech.* no. 8, 311–322, Aug. 1952.

505. Maresca, G., On thermoelastic phenomena in cast asphalt (in Italian), *Ric. sci.* **22,** 8, 1593–1595, Aug. 1952.

Thermoelastic retirements in floated asphalts are observed and measured. The note deals with the mechanism of this phenomenon and with the first experimental results.

From author's summary

506. Wygant, J. F., and Kingery, W. D., Thermodynamics in ceramics. I. Energy and heat content. II. Free energy, entropy, and equilibrium. III. Stability of ceramic materials, *Amer. ceram. Soc. Bull.* **31,** 5, 6, 7; 165–168, 213–217, 251–255; May, June, July 1952.

In the first paper, concepts of energy and heat content are considered, together with their application to various ceramic processes. In the second paper, thermodynamic concepts of free energy, entropy, and equilibrium are considered. Examples of ceramic calculations are given. The application of these to ceramic calculations is also considered. In the third paper, the stability of ceramic materials under the processes of (1) dissociation, (2) reaction, (3) vaporization, and (4) oxidation-reduction is considered. The prediction of stability of ceramic systems on the basis of thermodynamic calculations is illustrated for these cases.

From authors' summary

507. Wygant, J. F., and Kingery, W. D., Applications of thermodynamics in ceramics. IV. Crystal chemistry, physical processes and surface effects, *Amer. ceram. Soc. Bull.* **31,** 8, 294–297, Aug. 1952.

A thermodynamic approach to crystal chemistry, physical processes, and surface effects is considered. The correlation of these and other branches of science in ceramics by energy considerations is illustrated.

From authors' summary

508. Kawashima, S., and Kimura, H., Measurement of the internal friction of metal wire ropes through the longitudinal vibration, *Mem. Fac. Engng. Kyushu Univ.* **13,** 1, 119–130, 1952.

Logarithmic decrements in free longitudinal vibration at low and medium stress levels were measured for several wires and stranded cables. Specimens were approximately 12 ft long, were clamped at the upper end, and were loaded at the lower end by weights to various steady axial stresses. Longitudinal vibrations were initiated by an electromagnet, and displacements were measured by an electrical capacitance-type gage and were recorded vs. time. Free vibration frequencies were of the order of 10 cps. Curves showing logarithmic decrement vs. amplitude for various axial loads are given for several types of wire rope, and are compared with values obtained for the wire itself. For the steel and copper wires tested, the logarithmic decrements were practically independent of axial load, while for the multiple-strand wire ropes, the decrements were markedly reduced as the axial load was increased. Measured decrements vary from minimum of 0.001 for the steel wire to 0.4 for a $^1/_4$-in. 6-37 hemp-core steel-wire rope at low stress levels.

Donald E. Hudson, USA

509. Fast, J. D., and Dijkstra, L. J., Internal friction in iron and steel, *Philips tech. Rev.* **13,** 6, 172–179, Dec. 1951.

Most of paper reviews with great clarity the general technique of measuring low-stress internal friction at frequencies of order of one cycle per sec, damping caused by interstitially dissolved atoms, and use of damping measurements to study precipitation of carbides and nitrides from iron after quenching. Very few references to the extensive existing literature are given. Paper presents new information indicating that presence of 0.5% manganese in iron does not affect precipitation of carbide but materially retards that of nitride. Connection with magnetic aging phenomenon is suggested.

J. G. Leschen, USA

510. Tolansky, S., and Nickols, D. G., Interferometric studies of hardness test indentations: Investigations on tungsten carbide, steel, duraluminum and tin, *Phil. Mag.* (7) **43,** 339, 410–421, Apr. 1952.

Studies are made on the surface distortions which occur on metal surfaces which have received hardness-test indentations from both diamond-pyramid and diamond-cone indenters. The surface contours are evaluated by multiple-beam interference-methods.

Experiments are reported for indentations over a wide range of hardness, the surfaces studied being those of sintered tungsten carbide, nickel-steel, duraluminum, and tin. The distortions found in polycrystalline masses resemble one another, but reveal secondary differences.

On single crystallites of tin, unsymmetrical patterns are found, with piling-up in two directions and sinking-in in directions at

right angles to these. The effects are determined by the directions of the crystal axes.

The concavity and convexity of the sides of the pyramid indentations are discussed in relation to piling-up and sinking-in, and the influence of recovery is indicated.

From authors' summary by R. Hill, England

511. **Grossmann, M. A., Elements of hardenability,** American Society for Metals, Cleveland, 1952, 164 pp.

Book deals with the hardenability of steels, or the capacity of steel to harden when subjected to a given heating and quenching cycle. Author discusses background and development of quantitative tests and measurements of hardenability. The time-temperature relations for the isothermal transformation of austenite to ferrite and carbide are described, and these are then correlated with the results of Jominy tests. The effect of grain size on velocity of austenite transformation is also pointed out. Author goes into considerable detail in summarizing the physics of quenching and treating the subject quantitatively. A final chapter discusses effects of alloying elements on hardenability, including effects of Ge, H, O, and N. There are 130 references listed. Book is an amplification and revision of portions of "Principles of heat treatment" by the same author. An excellent book for beginners or experts in the field of hardenability. C. A. Keyser, USA

512. **Allen, N. P., Recent European work on the mechanical properties of metals at low temperatures,** "Mechanical properties of metals at low temperatures," *Nat. Bur. Stands. Circ.* 520, 1–35, May 1952.

A brief account is given of work in Europe since 1940 on the mechanical properties of metals at low temperatures. Elasticity and plasticity are dealt with, and the development of brittleness at low temperatures is discussed in relation to brittle fracture in mild steel, the behavior of heat-treated alloy steels at temperatures prevailing in the stratosphere, and the reliability of austenitic steels at liquid-air temperature. The properties at low temperatures of pure alloys of iron made at the National Physical Laboratory are described, and it is shown that some alloying additions exert influences on the rupture strength that are independent of their influence on the resistance to plastic deformation.

From author's summary by Aaron Wexler, USA

Mechanics of Forming and Cutting

(See also Rev. 391)

513. **de Groat, G., Ingenious tools make complex metal-powder parts,** *Amer. Mach.* **96,** 18, 105–109, Sept. 1952.

Unusual pressing tools for making complex powdered-metal parts and sizing equipment for holding close tolerances are described. From author's summary

514. **Chao, B. T., Trigger, K. J., and Zylstra, L. B., Thermophysical aspects of metal cutting,** *Trans. ASME* **74,** 6, 1039–1049, Aug. 1952.

See AMR 5, Rev. 1432.

515. **Chung, S. Y., and Swift, H. W., Cup-drawing from a flat bank: Part I. Experimental investigation. Part II. Analytical investigation,** *Instn. mech. Engrs., appl. Mech.* **165** (W.E.P. no. 68), 199–223, Proc. 1951.

Experimental section gives results of comprehensive series of tests using low-carbon steel, aluminum, brass, and copper. Effects of blank-holding force, drawing ratio, die-profile radius, blank-thickness, punch profile, and mechanical properties of blank materials on punch loads, total process work, drawing capacity, and various strain components are examined. The results are interpreted in the light of the properties of the blank material and the deformation processes involved. The analytical section does not claim to be an exact treatment of the problem. Authors consider the problems of radial drawing and bending over the die. With reasonable approximations and assumptions of work-hardening and friction, they predict drawing strains, punch loads, and total work in good agreement with experiment. This agreement appears to confirm the substantial validity of the model treated.

Reviewer believes this to be a paper which will repay careful study by those practically interested. The data provided will be of considerable value in future theoretical work.

J. F. W. Bishop, Scotland

516. **Shaw, M. C., Smith, P. A., and Cook, N. H., The rotary cutting tool,** *Trans. ASME* **74,** 6, 1065–1073, Aug. 1952.

Discussion of basic requirements in tool design due to cutting speed, tool temperature, and friction between chip and tool. Tests of HSS rotary lathe tool are correlated to those conducted with corresponding single point tools. Rotary tool had temperatures lower than the equivalent stationary tool; at optimum cutting speeds the difference was as much as 400 F. Rotary tool has constantly changing cutting edge which can absorb a film of air or fluid when not cutting. Other advantages analyzed include greater relative velocity between chip and tool, and greater effective rake angle. With tool rotating at 80% of the cutting speed, total power will be 30% less than that of a corresponding stationary tool. Rotary tool life was better.

A. O. Schmidt, USA

517. **Eugène, F., Contribution to the study of the wear of cutting tools** (in French), *Rev. Métall.* **49,** 4, 267–282, Apr. 1952.

Paper is divided in two parts. Part I deals with observations of wear of cutting tools and hydrodynamic model simulating metal flow past tools. Mode of wearing (cratering, cratering plus front-face wear, front-face wear only) depends on cutting angle and cutting speed. For low cutting speed and high cutting angle (low rake), adherent metal on edge of tool causes compression of metal in front of tool. Adherent metal protects front-face, and chip wears (craters) face of tool away from edge. For high speeds and low cutting angles (high rake), the machined metal is no longer compressed in front of the tool but rubs against the front face; high front-face wear results.

Part II discusses method of studying intrinsic wear resistance of cutting tools (determined by energy loss by friction, and weight loss by tool) as function of cutting temperature. Tests show that intrinsic wear vs. temperature curves are independent of hardness of steel machined, but are quite sensitive to changes in cutting-tool composition. L. F. Coffin, Jr., USA

Hydraulics; Cavitation; Transport

(See also Revs. 337, 365, 470, 535, 640)

518. **Citrini, D., Pressure movements with variable rate of flow along the conduit** (in Italian), *Energia elett.* **29,** 5, 277–285, May 1952.

Author studies problem of variable flow when rate of flow increases and when it decreases along the course. First, he assumes case of no loss of head, and applies momentum equation to flow in a conduit with uniformly distributed orifices, which collects a liquid from a reservoir. He arrives at a differential equation between dimensionless variables. Author applies finite differences

to the solution of that equation. This leads to the calculation of the total rate of flow. Author outlines the general solution with loss of head.

Similarly, he treats the inverse problem of an end-closed perforated conduit with decreasing rate of flow. He applies the energy equation this time with no head losses. Again he outlines the solution when the problem with losses is considered.

Reviewer believes this paper is a very important contribution to this subject, but it is expected that more research will be done to entirely solve the problem when the real case with head losses along the conduit is considered. A. Balloffet, Argentina

519. **Glover, R. E., Herbert, D. J., and Daum, C. R., Solution of an hydraulic problem by analog computer,** *Proc. Amer. Soc. civ. Engrs.* **78,** Separ. no. 134, 7 pp., June 1952.

An electronic analog computer is described that serves to investigate the flow in a network of channels in a delta area influenced by tidal effects. Stress is laid upon the representation of the square-law resistance that is essential for the smaller channels. The equations correlating hydraulic and electrical quantities are developed, and the methods by which the boundary conditions are introduced are discussed.

F. A. Willers, Germany

520. **Maitre, R., Study of the working conditions of surface spillways with partial opening of gates** (in French), *Houille blanche* **7,** 2, 232–244, Apr. 1952.

A theoretical and experimental investigation of the pressures along a curvilinear overflow spillway, when the crest gate is partly closed. The negative pressures can influence the stability of the nappe and force it to separate from the bottom. The maximum depression has been determined theoretically and checked on laboratory models of the Creager profile (parabola of 1.8 degree) and simple parabolic profile. Observations made on two existing dams show that separation of the nappe occurs at lower depressions than deduced from model tests. When a larger profile cannot be adopted for economical reasons, the author suggests locating the taintor gate downstream below the crest and trying to reduce to the minimum the deflection of the nappe.

Steponas Kolupaila, USA

521. **Meyer, R., On the influence of turbulence on the fall of solid particles in water** (in French), *Houille blanche* **7,** 2, 283–288, Apr. 1952.

Discussion of a previous paper by M. Bouvard [AMR **5,** Rev. 2647]. Equations and approximations used to describe the movement of material in suspension are analyzed. Inertial forces are taken into account, combined with the effect of dissymmetry of the drag law, which was studied by Bouvard.

D. Citrini, Italy

522. **Dobrowsky, A., On an algebraic calculation of axisymmetric diffusion and its representation by a hydrodynamic model (method of stream dividers)** (in German), *Kolloid Z.* **126,** 1, 1–14, Apr. 1952.

Author states that he has developed a numerical procedure for the solution of the diffusion equation for axisymmetric diffusion (actually, a two-dimensional source) for which he first requires the flow net for potential flow. This procedure evidently depends only on the geometrical properties of a triangular sector of the flow field. No proof or justification for the method is given, but comparisons between this method and the solution in terms of Bessel functions for diffusion from a cylindrical source show good agreement. The "hydrodynamic model" is a system in which flow through banks of capillary tubes arranged in series is adjusted to produce pressure drops proportional to the spatial variation in concentration. Phillip Eisenberg, USA

523. **Davies, R. W., Turbulent diffusion and erosion,** *J. appl. Phys.* **23,** 9, 941–948, Sept. 1952.

A new theory of turbulent diffusion is developed to describe the dynamics of particles suspended in fluids. For the statistical description to be consistent with force equation dynamics of sedimentation, a new diffusion equation is derived from the postulates of a past-future stochastic process. A steady-state suspension of particles in a turbulent stream is treated like an atmosphere. Dimensional arguments are used to retain the most relevant physical entities in a linear theory. It is shown that the bed load and midstream suspension of a muddy stream cannot be considered separately. Experiments are discussed in this connection. A qualitative theory of sand rippling is explained in terms of the instability of a flat sandy bottom under certain turbulence conditions. A singular perturbation method is employed to obtain an asymptotic expansion of the solution of the equilibrium equation.

From author's summary by Neal Tetervin, USA

524. **Kohler, M. A., Application of electronic flow routing analog,** *Proc. Amer. Soc. civ. Engrs.* **78,** Separ. no. 135, 11 pp., June 1952.

An electronic device for stream-flow routing, recently developed in the U. S. Weather Bureau, has proved to be a very effective tool in preparation of river flood forecasts. It was designed for quick integration of the inflow and the storage for a certain reach of river, resulting in the synthesis of its outflow. Although originally designed for routing flows point to point along a stream, it was applied successfully for direct integration of the runoff over whole basin areas. This process is performed electrically, adjusting the resistances and capacitances of condensers in the circuit, corresponding to the assumed form of storage equation. Paper demonstrates several simple and more complicated examples of application of such equations. In its present form, the electronic flow analog is limited to the simple equation, when storage is assumed to be proportional to flow; actually, this simplification yields satisfactory results in most cases. Therefore, the U. S. Weather Bureau is planning to introduce this device in all its river forecast centers. Steponas Kolupaila, USA

525. Redding, T. H., Bibliographical survey of flow through orifices and parallel-throated nozzles, London, Chapman & Hall, Ltd., 1952, 196 pp. 32s 6d.

Book contains 609 references to work done between 1832 and 1946 on flow through orifices (of circular aperture) and parallel-throated nozzles, with special reference to flowmetering methods. References are listed under 16 subject headings; cross indexing is provided at the end of each subject category. An author index is also provided. A short abstract of each reference is given, indicating the scope and general nature of each work. Various metering arrangements are described in the introduction, and a glossary of terms commonly used in flowmetering is given in an appendix.

Format of book is excellent; reviewer feels that completeness of the work justifies book form for the bibliography and makes it a valuable reference text. A. Shaffer, USA

526. **Dayal, B., Surface tension and melting point,** *Nature* **169,** 4311, p. 1010, June 1952.

Author discusses a useful relation [Weale, title source, **168,** p. 343, 1951] between the translational part of the thermal energy of the molecular surface layer, the surface tension, and the melting point. Given either the molecular association factor or the cross-

sectional area of the molecule, the other can be calculated with fair agreement with values obtained from x-ray data. Reviewer notes that Dayal's definition of melting point applies to those liquids where the net force of intermolecular attraction is effective over a single intermolecular distance, and should read: "The melting point may be defined as the temperature where the translational part of the thermal energy of the molecules in the surface layer becomes equal to the surface tension of the liquid expressed in energy units." Bruce R. Mead, USA

527. Lee, S.-Y., and Blackburn, J. F., Contribution to hydraulic control. 2. Transient-flow forces and valve instability, *Trans. ASME* **74,** 6, 1013–1016, Aug. 1952.

Starting with simple formulation of momentum equation for unsteady flow, authors develop a criterion for stability of a 4-way valve in a simple oil-hydraulic circuit. Differential equation of valve motion is derived but not solved. Criterion is obtained from sign of damping term in equation. Results of one test of valve having no steady-state force [see AMR **5,** Rev. 1116] are presented as verification. Reviewer believes that quantitative tests will be necessary before proof is definite. Paper is recommended for designers of servo systems.

W. D. Baines, Canada

528. Escande, L., Investigation of the operation of spill gates (in French), *Bull. Acad. Serbe Sci., Cl. Sci. tech.* **8,** 2, 31–49, 1952.

Paper gives results of experiments made on spill gates having the shape of a Creager profile and rotated around a horizontal axis near the bulkhead. The rate of flow, the free surface, the distribution of pressure, and total force on the gate have been determined for various positions and lengths of the gate. Author does not state what practical problem led to such a study.

A. Leclerc, Canada

529. Jorissen, A. L., Discharge coefficients of Herschel-type Venturi tubes, *Trans. ASME* **74,** 6, 905–913, Aug. 1952.

This report covers the variation of the discharge coefficients of more than 200 tubes. Author found that coefficients generally fell within a band that was limited by $\pm 0.75\%$. It is unfortunate that no clear definition is given for his C_s, and no definition is given for his Reynolds number. There is no way of determining from the paper whether the Reynolds number is based on inlet or throat conditions. Excellent discussions are given by I. O. Miner, A. Schlag, and W. S. Pardoe. Glen N. Cox, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 372, 518, 604, 627, 650, 692)

530. Manera, G., The principle of conservation of energy, after Lagrange, in liquids at rest (in Italian), *Atti Accad. Sci. Torino I. Cl. Sci. Fis. Mat. Nat.* **85,** 348–354, 1950–1951.

The author's equation (5) is $\rho d\phi = dp$, which is equivalent to the equation of hydrostatics. The remainder is valid only subject to the unstated assumption that compressibility ϵ is the same at all densities. The result is an expression for $d\phi$ in terms of ϵ and dp. Thus the title is rather misleading. C. Truesdell, USA

531. Riegels, F., Flow around slender, almost rotationally symmetric bodies (in German), *Mitt. Max-Planck-Inst. Strömungsforschung* no. 5, 72 pp., 1952.

The flow around a slender body of nearly circular cross section at incidence is represented by replacing the body by the equivalent ring source-sink distribution. The method involves the solution of an integral equation by an iteration process. Tabulated values of certain necessary functions are given.

The method has been checked against the exact solution for an ellipsoid, and good agreement was obtained. The application of the method to a body having a triangular cross section with curved corners is also discussed. G. M. Lilley, England

532. Pond, H. L., The pitching moment acting on a body of revolution moving under a free surface, *David W. Taylor Mod. Basin Rep.* 819, 13 pp., May 1952.

The moment acting on an elongated body of revolution moving parallel to its axis along a horizontal line under a free surface is calculated, following a procedure similar to the one previously employed by the author for the case of the Rankine ovoid [title source, 795, 17 pp., Nov. 1951]. The moment is expressed in terms of the doublet distribution $\vec{u}$, that describes the axial motion of the body in an unbounded fluid. First, the potential function for this doublet distribution in the presence of the free surface is obtained, using a result of Havelock for the effect of the free surface upon potential of a single doublet. The resulting distortion of the body is approximately corrected by the addition of another doublet distribution $\hat{u}$ directed vertically and chosen in accordance with von Kármán's approximation for the superposition of a vertical velocity distribution on the flow about an elongated body of revolution in an infinite fluid; in this case, the vertical velocity distribution is that induced by the free surface and is derived from the previously obtained potential function. Applying a well-known approximate relationship between the shape of the body and the doublet distribution $\vec{u}$, the geometric factor in the von Kármán formula is removed. An application of Lagally's theorem then obtains a general explicit expression for the pitching moment.

Reviewer suggests that the results should be applied to a few specific examples in order to determine how well the distortion of the body is corrected and the extent to which agreement with experimental results can be expected. Leonard Pode, USA

533. Greidanus, J. H., van de Vooren, A. I., and Bergh, H., Experimental determination of the aerodynamic coefficients of an oscillating wing in incompressible, two-dimensional flow. Part I. Wing with fixed axis of rotation, *Nat. LuchtLab. Amsterdam Rep.* F. 101, 27 pp., 26 figs., Jan. 1952.

This paper represents the first of three phases of an experimental program designed to obtain information concerning the validity of the well-known linearized method of calculating aerodynamic coefficients for oscillating airfoils.

Measurements of forces and moments on a two-dimensional airfoil oscillating about a fixed axis of rotation are used to determine the three quantities, k_a, m_b, and $k_b + m_a$, where k_a is the aerodynamic force coefficient (a.f.c.) of translation, k_b is a.f.c. of rotation, m_a is a.f. moment c. of translation, m_b is a.f.m.c. of rotation.

The separation of k_b and m_a will require additional experiments in which the axis of rotation itself performs a vertical oscillation.

The third and final planned phase of this program will consist of a calculation of the derivatives, including corrections for wind-tunnel effects.

The results of this first phase of the program indicate excellent agreement with linearized theory, although final conclusions await completion of the other two phases.

It is particularly interesting to note that the location of the transition of the boundary layer from laminar to turbulent is a major factor contributing to the aerodynamic moment coefficients. This factor was given special consideration in the present work, and, although the major portion of the measure-

ments was made with a boundary-layer trip wire on the model, some tests were conducted without this wire.

The discrepancy in experimental results between tests with a trip wire and those without the wire was large, but was the greater with the axis of rotation at the quarter-chord point and at a Reynolds number of 0.3×10^6. The transition at this Reynolds number is still close to the trailing edge, but a change in transition point location is most important when it occurs near the trailing edge. This is strong evidence to support the contention that the discrepancy in the results of the trip and no-trip tests is due to the boundary layer.

It thus appears as though the linearized theory cannot produce reliable results at or near the critical Reynolds numbers.

M. Alperin, USA

534. **Lawrence, H. R., and Gerber, E. H., The aerodynamic forces on low-aspect-ratio wings oscillating in an incompressible flow,** *Cornell aero. Lab. Rep.* AF-781-A-1, 42 pp., Jan. 1952.

The exact two-variable integral equation for an oscillating lifting surface in linearized incompressible flow is reduced to a single-variable equation applicable to wings with straight trailing edges and of low aspect ratio. This equation is solved by collocation, using a simplified matrix notation and arrangement which simplifies necessary reciprocations.

Agreement is found between the present development and the limiting cases of $AR = \infty$ and $AR = 0$, as determined by two-dimensional theory and Jones extended theory, respectively. Results of calculations of the lift and moment coefficients for rectangular and triangular wings of aspect ratio zero to aspect ratio four are presented in tabular and graphical form.

J. B. Duke, USA

535. **Lin, P.-N., Numerical analysis of continuous unsteady flow in open channels,** *Trans. Amer. geophys. Un.* **33,** 2, 226–234, Apr. 1952.

Paper is based on Massau's equations of characteristics and presupposes the reader's familiarity with that paper. It shows how the amount of work may be reduced in the trial-and-error solution by the choice of constant time intervals.

H. A. Einstein, USA

536. **Bisplinghoff, R. L., and Doherty, C. S., Some studies of the impact of vee wedges on a water surface,** *J. Franklin Inst.* 253, 6, 547–561, June 1952.

A brief résumé is given on the background and present status of the two-dimensional vee-wedge theory. Fundamental assumptions are reviewed, and the problem, including buoyancy forces, is formulated with arbitrary amounts of wing lift. The unsteady-state force is derived, using the flow pattern about an expanding prism. A formula for the shape of the free-water surface is derived, based upon Wagner's assumption and using the flow about an expanding prism. Two-dimensional experiments are described in which accelerations are measured, and high-speed photographs of the piled-up water were taken. Experimental and theoretical results are compared.

From authors' summary by G. V. R. Rao, USA

537. **Polubarinova-Kochina, P. Ya., On the filtration in two soils with a slanted separation line** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 1, 11–20, Jan. 1952.

A thin wedge of soil ($0 < y < ax$) with constant filtration coefficient k_1 lies on a level impervious layer, and is covered by soil for which $k = k_2$. Water enters at constant rate q across a distant ordinate; and the shape of the resulting nonsteady water table is studied. Horizontal velocity is given by $u = -k\,dh/dx$, where h is the height of the water surface above $y = 0$. Then $q = -[k_1 ax + k_2(h - ax)]dh/dx$ governs the system. The paper is primarily concerned with solutions of this differential equation for various magnitudes of the parameters involved.

R. E. Gaskell, USA

538. **Ivakin, V. V., On the question of filtration into non-saturated soil** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 12, 1874–1880, Dec. 1951.

Criticism of paper reviewed in AMR **5,** Rev. 2209.

539. **Goldstein, S., Approximate two-dimensional airfoil theory. Parts I, II, IV, V;—and Richards, E. J., Part III;—and Preston, J. H., Part VI,** *Aero. Res. Counc. Lond. curr. Pap.* 68, 69, 70, 71, 72, 73; 56 pp., 3 figs.; 53 pp., 8 figs.; 36 pp., 8 figs.; 49 pp.; 25 pp.; 40 pp.; 1942, 1943, 1944, 1945, published 1952.

Papers contain complete development of approximate two-dimnsional airfoil theory previously presented in summary form by Goldstein at Wright Brothers lecture, Dec. 1947 [see AMR **1,** Rev. 882]. Part VI (Aerofoils with hinged flaps), not described in afore-mentioned lecture, extends theory to title case.

B. Etkin, Canada

540. **Kotchin, N. E., The theory of waves generated by oscillations of a body under the free surface of a heavy incompressible fluid,** *Soc. nav. Arch. Mar. Engrs., Tech. Res. Bull.* no.1–10, 39 pp., 1952.

Translated from *Uchenïye Zapiski Moskov. Gos. Univ. Mekhanika* **46,** 85–106, 1940.

541. **Yamada, H., and Taneda, S., Note on the liquid motion in U-tube,** *Rep. Res. Inst. Fluid Engng., Kyushu Univ.* **7,** 1, 1–13, Sept. 1950.

The customary use of Poiseuille's law of friction in the study of liquid motion in small tubes leads sometimes to inaccuracy. In this note, equations of the laminar motion of liquid column of finite length in a circular tube under gravity, caused by a given pressure at one end, are solved; time relations and frictions are examined and proved by the U-tube experiments. Applicability of the free oscillations to viscometry is discussed.

From authors' summary

542. **Garabedian, P. R., and Spencer, D. C., Extremal methods in cavitational flow,** *J. rational Mech. Analysis* **1,** 3, 359–409, 1952.

The basic principles of minimum virtual mass and of maximum least velocity are developed for two-dimensional free surface flows, and some of the results of the behavior of virtual mass under symmetrization are discussed. Proofs for the existence of plane cavitational flows are developed in turn from both principles. The problem of free surface flows in a gravity field is discussed, and some generalizations of the principles to axially symmetric flows are made. The article concludes with a discussion of finite wakes and water entry. Lawrence Talbot, USA

543. **Gilmore, F. R., The growth or collapse of a spherical bubble in a viscous compressible liquid,** Heat Transf. Fluid Mech. Inst., Stanford Univ. Press, 53–64, 1952. $4.

Author develops differential equations for bubble growth or collapse in systematic fashion, making usual approximations, including Kirkwood-Bethe assumption concerning propagation of disturbances. He shows how solutions for bubble-wall motion may be obtained analytically and numerically, and presents result of computation for one case which agrees quite well with that

obtained by numerical integration of partial differential equations. For other numerical results, reader is referred to forthcoming reports from Hydrodynamics Lab., Calif. Inst. Tech.
J. A. Lewis, USA

544. Weinblum, G. P., On hydrodynamic masses, *David W. Taylor Mod. Basin Rep.* 809, 15 pp., Apr. 1952.

The concept of the additional virtual masses of submerged bodies moving in infinite medium leads to the use of characteristic mass and inertia factors whose numerical values may, in simple cases, be calculated and referred to the mass and inertia of the homogeneous body having the density of the medium. The concept remains suitable in the case of bodies which, like a ship, move on the free surface of the water, provided that formation of waves is taken into account.

Author gives a fair review of the present status of knowledge of the last subject. Only few solutions for some simple kinds of motions are known, from which the dependence of the hydrodynamic masses from an acceleration parameter, from the Froude number, from a frequency parameter, etc., can be established. In more realistic problems, coarse estimates are often used for technical applications, but no satisfactory general solution is known. May this introductory T.M.B. report promote serious endeavors in this field. R. Spronck, Belgium

545. Hughes, R. R., and Gilliland, E. R., The mechanics of drops, Heat Transfer Fluid Mech. Inst., Stanford Univ., 53–72, 1951. **$5.**

As a preliminary to a general study of mass transfer in fluid particle systems, an analysis is made of the mechanics of drops. The general review presented includes both the gross motion of drops and the detailed motion in and around individual drops. The emphasis of the review is on new concepts and correlations in connection with the effect of acceleration on drag, the equilibrium distortion, and the internal circulation caused by skin friction.
From authors' summary by Bruce R. Mead, USA

546. Kotchin, N. E., On the wave-making resistance and lift of bodies submerged in water, *Soc. nav. Arch. mar. Engrs., Tech. Res. Bull.* no. 1–8, 125 pp., 1 plate, 1951.

Translated from Central Aero-Gidrodinam. Inst. Moscow, 1937, pp. 65–134.

547. Gotusso, G., On a variational principle in viscous liquids (in Italian), *Atti Accad. Sci. Torino* **85,** 380–388, 1950–1951.

Author obtains for a viscous incompressible fluid a variational principle for slow motions and irrotational motion within a finite region, for which the condition of zero velocity at the boundaries of the region is not demanded. He then shows (incorrectly) that adding the condition of zero velocity at the boundaries makes the dissipation function vanish everywhere, and at the same time he fails to note that this result is trivially correct in the case of the irrotational motion, since adding this condition makes the velocity zero everywhere. Author claims results also apply when the flow region is infinite, but gives no discussion of the change in the various boundary conditions when this is the case. P. Chiarulli, USA

548. van der Does de Bye, J. A. W., and Schenk, J., Heat transfer in laminar flow between parallel plates, *Appl. sci. Res.* (*A*) **3,** 4, 308–316, 1952.

The problem is solved for a mixed boundary condition at the wall, i.e., finite-wall Nusselt number. Numerical calculations are carried out for Nusselt number of 2 and 20 for the first three eigenvalues. An interpolation scheme is given for arbitrary Nusselt number. The corresponding problem for a circular pipe should not involve anything new. Assumption that fluid properties are independent of temperature is employed.
William Squire, USA

549. Dizioglu, B., The average temperatures in lubricating layers between parallel heat-insulated walls (in German), *Rev. Fac. Sci. Univ. Istanbul* (*A*) **17,** 61–65, 1952.

Paper deals with the problem of finding the temperature distribution in a steady one-dimensional flow of incompressible viscous fluid under pressure between two parallel and heat-insulated plates, moving relatively with a constant velocity. By neglecting the conduction of heat in the downstream direction, problem is shown to be reducible to a boundary-value problem of the Sturm-Liouville type. From the orthogonal relations, author deduces that the heat carried by convection at any section is equal to the total heat dissipated in the volume bounded by that section. The consequence of this is that the average temperature, defined in terms of the convected heat, increases linearly as the distance from the initial section in the downstream direction. It might be remarked that this result can be simply obtained by integrating the energy equation without knowing the temperature distribution. Y. H. Kuo, USA

550. Kotchin, N. E., The two-dimensional problem of the steady oscillations of bodies under the free surface of a heavy incompressible liquid, *Soc. nav. Arch. mar. Engrs., Tech. Res. Bull.* no. 1–9, 40 pp., 1952.

Translated from *Izv. Akad. Nauk SSSR Otd. tekh. Nauk*, pp. 37–62, 1939.

Compressible Flow, Gas Dynamics

(See also Revs. 543, 578, 581, 582, 585, 586, 591, 598, 614, 623, 665, 666)

551. Bureau of Ordnance, Handbook of supersonic aerodynamics, Super. Doc., U. S. Gov. Print. Office, Washington, *Navord Rep.* 1488 (vol. 4), 122 pp., Jan. 1952. $1.25.

Section 12 of Volume 4 contains derivation of the equation for torsional flutter of a two-dimensional wing in supersonic flow, supplemented with tables of the real and imaginary parts of the supersonic force and moment flutter coefficients. Included also are brief discussions of binary and ternary flutter of two- and three-dimensional airfoil with a numerical example.

Section concludes with a comprehensive list of references on aeroelastic phenomena. A. Petroff, USA

552. Shen, S. F., Note on the distribution of singular directions of two-dimensional shock, *J. Math. Phys.* **31,** 2, 102–108, July 1952.

By assuming that a body with an analytic shape in a supersonic flow produces an analytic shock shape, Thomas [AMR 5, Rev. 1802] found certain singular shock directions associated with each derivative of the shock curvature. The present paper shows that the set of singular shock directions for the various derivatives of the curvature is ordered such that the singular directions associated with succeedingly higher derivatives of the curvature become less in slope as the order of the derivative is increased. Hideo Yoshihara, USA

553. Barish, D. T., and Guderley, G., Asymptotic forms of shock waves in flows over symmetrical bodies at Mach one, *AF tech. Rep.* 6660, 20 pp., Jan. 1952.

The shape of the shock at a far distance from either a planar or

axial-symmetric body is investigated, using the usual transonic approximation. By a suitable product hypothesis for the solution, the problem is reduced essentially to finding a solution of a nonlinear ordinary differential equation fulfilling boundary conditions as well as a "jump" condition, the latter at a location which is not known in advance. The solution is then carried out by a numerical procedure. Hideo Yoshihara, USA

554. **Newton, R. G., A progressing-wave approach to the theory of blast shock,** *J. appl. Mech.* **19, 3,** 257–262, Sept. 1952.

A successive-approximation method of analysis is given for the spherical shock wave formed by an explosion in free air. Essentially starting with Taylor's similarity relation (shock-front radius proportional to the time to a constant power), but keeping the pressure relations more general, a solution is obtained satisfying both the potential equations for spherical flow and the Rankine-Hugoniot shock relations. Then the energy integral is applied with the condition that the excess energy in the shock sphere, above that of the enclosed heat energy of the still gas, must be equal to the energy originally released by the initial explosion. It is found that the asymptotic behavior of the solution can satisfy the energy relation only if the value of the time exponent varies as the wave front progresses.

The pressure relations near the start of the shock, regarded as a point explosion, are still similar to Taylor's high-pressure approximation. E. V. Laitone, USA

555. **Kistiakowsky, G. B., Knight, H. T., and Malin, M. E., Gaseous detonations. III. Dissociation energies of nitrogen and carbon monoxide. IV. The acetylene-oxygen mixtures. V. Nonsteady waves in CO-O_2 mixtures,** *J. chem. Phys.* **20,** 5, 6; 876–883, 884–887, 994–1000; May, June 1952.

Previous papers of series reviewed published theory and experimental data on shock wave of gas detonation as balance between chemical generation and mechanical dissipation of energy. Equipment and technique of authors were described. Results for hydrogen-oxygen mixtures supported the thesis that chemical equilibrium is frequently attained within shock wave, thus making speed of wave a fixed function of initial state of reaction mixture.

Paper III indicates that quantitative reaction of equimolar mixture of cyanogen and oxygen would give a carbon-dioxide-nitrogen mixture at > 7000 K ($> 12{,}000$ F) within the shock wave. Probably chemical equilibrium is established in wave front, and detonation velocity thus becomes a measurement of extents of dissociation of product gases. Modifications of equipment and techniques for handling reagent gases are described. As theory predicts, wave speed is inversely proportional to tube diameter. Experimental results are consistent and reproducible. Best correlation of measured and calculated speeds is obtained with dissociation energies of 9.76, 11.1, and 8.0 ± 5 electron volts for nitrogen, carbon monoxide, and cyanogen, respectively.

Test samples had been ignited by shock waves from acetylene-oxygen mixtures, thus indicating their properties. Paper IV describes preparation of acetone-free acetylene; other techniques and equipment were given earlier. Speed of detonation varies greatly with composition and shows a sharp maximum. Sufficient excess acetylene leads to irregular, relatively high-speed shock waves. The reaction products include finely divided carbon. It is postulated that gaseous carbon is formed in the shock wave, but precipitation of solid particles requires more time. This improves correlation between measured and calculated rates, but a noticeable discrepancy remains.

Paper V describes work with mixtures of carbon monoxide and oxygen. Commercial carbon monoxide, anhydrous but containing some methane, yielded smooth detonations. Carbon monoxide free from any source of hydrogen gave unsteady waves and much luminescence in regions outside or apart from shock waves. Apparently a shock wave cannot maintain itself through fresh-gas mixture because reactions within the wave are incomplete. The partly converted mixture continues to react and increase in temperature. Secondary detonating waves are formed in this heated zone. Such waves overtake the frontal waves, thereby becoming frontal waves themselves and slowing down to be overtaken in turn. Spinning detonations may be due to influence of walls in relatively small tubes. They were not observed in present work. The irregular changes of orientation of frontal waves prevent treatment as a unidimensional process. Findings to date do not permit conclusive choice between alternative theoretical explanations. Jack D. Bush, USA

556. **Owen, P. L., and Thornhill, C. K., The flow in an axially-symmetric supersonic jet from a nearly-sonic orifice into a vacuum,** *Aero. Res. Counc. Lond. Rep. Mem.* 2616, 8 pp., Sept. 1948, published 1952.

Numerical calculation uses method of characteristics. Theory of flow near axis is given special consideration. Good agreement is found between theoretical pressure distribution along axis and available experimental results. N. H. Johannesen, England

557. **Ishida, T., Notes on the designing of subsonic aerofoils by means of ideal fluid theory,** *J. Japan Soc. appl. Mech.* **5,** 26, 7–10, 1952.

Paper, not well written, refers to calculations of profiles having given velocity distributions. Because this method of successive approximations for an incompressible flow will not generally yield closed contours, it must be preceded by calculations on a variety of airfoils decomposed into mean camber lines and thickness distributions. Apparently, a judicious selection of a mean camber line and a thickness distribution gives a suitable start for the successive approximation that will lead to the profile required. For calculations in the compressibility range, it appears that the given pressure distribution is first reduced by the von Kármán-Tsien method to the incompressible flow equivalent, and then the latter is treated by the above method. Work on laminar flow airfoils receives special treatment. M. G. Scherberg, USA

558. **Shiffman, M., On the existence of subsonic flows of a compressible fluid,** *Proc. nat. Acad. Sci. Wash.* **38,** 5, 434–438, May 1952.

For the case of two-dimensional flow, with prescribed velocity at infinity, past an object with smooth outline, a unique flow field is shown to exist, provided the velocity everywhere is less than the local speed of sound. Variational principles are used to prove this theorem, which is also valid for a prescribed circulation about the object. The critical speed, which is the highest free-stream velocity consistent with a wholly subsonic field, depends only on the shape of the object and the circulation, if present.

Andrew R. Mitchell, Scotland

559. **Fettis, H. E., Tables of lift and moment coefficients for an oscillating wing-aileron combination in two-dimensional subsonic flow,** *AF tech. Rep.* 6688, 24 pp., Nov. 1951.

Report contains some preliminary results on the computation of lift and moment coefficients for an oscillating, flapped airfoil in compressible subsonic flow.

Included also are complete tables of the functions j_0, j_1, j_2, needed in the computations, as well as partially complete tables of some of the other special functions involved.

From author's summary

560. DeYoung, J., Theoretical antisymmetric span loading for wings of arbitrary plan form at subsonic speeds, *NACA Rep.* 1056, 36 pp., 1951.

Supersedes paper reviewed in AMR **4,** Rev. 2189.

561. Thornhill, C. K., The numerical method of characteristics for hyperbolic problems in three independent variables, *Aero. Res. Counc. Lond. Rep. Mem.* 2615, 13 pp., Sept. 1948, published 1952.

Author describes the classical characteristic properties of quasilinear hyperbolic differential equations of the second order in three independent variables, defining their characteristic surfaces, cones and conoids, and bicharacteristic curves; clear figures of these are shown. He then puts forward two methods of numerical integration of such equations based on characteristic properties, the first employing a hexahedral network of characteristic surfaces and the second a hexahedral network of bicharacteristic curves. In each method, a new point in the network is constructed by finding the fourth vertex of the cell based on three points where conditions are known. Details required in each method are developed in full for the equations of steady supersonic potential flow in space and of unsteady compressible potential flow in two dimensions, respectively. No numerical example is included.

Neither method is related to a definite system of characteristic coordinates and, in contrast to the method of Dolph and Coburn [AMR **3,** Rev. 1523], uniqueness cannot be rigorously established. Maurice Holt, England

562. Truesdell, C., Vorticity and the thermodynamic state in a gas flow, *Mém. Sci. math.* no. 119, 53 pp., 1952.

The two-fold objective of this memoir is ". . . to characterize irrotational gas flows in thermodynamical terms, and in rotational gas flows to search out the relations which bind the vorticity to the thermodynamical variables." For the most part, attention is concentrated on local properties of flows of inviscid compressible fluids subject to conservative (or vanishing) external force fields. Substantially all relevant known relations are derived (and sometimes extended) in a concise unified development. The major implications of these relations are summarized in carefully worded lemmas and theorems. The treatment is notable for its logical and systematic progression from the general to the particular. It starts by deriving results having a purely kinematic basis, then introduces dynamical considerations, then general thermodynamical ones, and finally, the minimum specialization of the thermodynamic properties of the fluid which leads to a substantial theory. Particular care is taken to point out and clearly state new hypotheses as they are introduced. This care is especially valuable in connection with the thermodynamic fundamentals—contrasting sharply with the usual fuzzy treatment of these matters. Historical credit for contributions to the theory is carefully given and well referenced in a 45-item bibliography running from 1762 (Lagrange) to 1952 (Truesdell).

R. C. Prim, III, USA

563. Oudart, A., Calculation of the compressible boundary layer. Practical elementary applications of the Oswatitsch-Walz and Gruschwitz-Walz methods (in French), *Publ. sci. tech. Min. Air, Paris,* no. 258, 66 pp., 1952.

This is a continuation of author's previous report [AMR **4,** Rev. 3641] and presents a collection of formulas and procedures for the practical calculation of laminar and turbulent boundary layers of compressible fluids, based on the methods of Oswatitsch and Walz, and Gruschwitz and Walz. The cases considered are flows over axially symmetric cones and fins on projectiles.

Y. H. Kuo, USA

564. Lomax, H., Heaslet, M. A., and Fuller, F. B., Integrals and integral equations in linearized wing theory, *NACA Rep.* 1054, 34 pp., 1951.

Paper supersedes AMR **4,** Rev. 2998. Concept of finite part of improper divergent integrals that arise in linearized wing theory is examined in detail. Main contribution to Hadamard's finite part technique is the introduction of a new notation which facilitates inversion of the order of integration when multiple integrals are expressed as repeated integrals. Also the concept of principal part in Cauchy's sense is generalized.

Application of generalizations to linearized wing problems in supersonic flow is given in some detail. (Reviewer notes that potential for elementary horseshoe vortex in subsonic flow is given incorrectly, but it is not used in sequel.) Operational technique based on generalizations is used to solve singular integral equations arising in wing problems, and constitutes a stimulating piece of work which should be read by all interested in the title subject. G. N. Ward, England

565. Nielson, J. N., and Pitts, W. C., Wing-body interference at supersonic speeds with an application to combinations with rectangular wings, *NACA TN* 2677, 63 pp., Apr. 1952.

A theoretical method is developed that permits determination of the pressure field of a wing-body combination having a circular body and a wing with supersonic leading and trailing edges. The complete problem is decomposed into a number of simpler problems, and the solution of each is discussed in turn. A Fourier type of analysis is used to determine the interference component of the potential. It is shown that good accuracy can be obtained in many applications through use of only a small number of the Fourier components. Numerous numerical results are presented and discussed. John R. Spreiter, USA

566. Miles, J. W., On interference factors for finned bodies, *J. aero. Sci.* **19,** 4, p. 287, Apr. 1952.

An elegant mapping procedure is used to extend Ward's result [AMR **3,** Rev. 529] for a body of two fins to one with n fins.

Hideo Yoshihara, USA

567. Hilton, J. H., Jr., Flow characteristics over a lifting wedge of finite aspect ratio with attached and detached shock waves at a Mach number of 1.40, *NACA TN* 2712, 21 pp., June 1952.

A series of schlieren photographs and pressure distributions are presented which show the effects of transition from an attached to a detached shock at the leading edge of a finite-span 8.2° wedge as the angle of attack is increased.

From author's summary

568. Young, A. D., and Kirkby, S., Application of the linear perturbation theory of compressible flow about bodies of revolution, *Aero. Res. Counc. Lond. Rep. Mem.* 2624, 8 pp , Sept. 1947, published 1952.

Authors show that for linearized subsonic compressible flow past slender bodies in three dimensions, the perturbation velocity is $1/(1 - M^2)$ times the perturbation velocity in incompressible flow. M denotes the Mach number of the free stream. Result is in agreement with that of Sears [AMR **1,** Rev. 141] and Lees [*NACA TN* 1127].

Result is applied to a family of bodies of revolution at zero angle of attack. Variations of maximum velocity with Mach number and fineness ratio are presented. Wind-tunnel interference factor is shown to be $1/(1 - M^2)^{3/2}$ times incompressible factor.

Reviewer's note: Paper was apparently completed in 1947 as College of Aero. Rep. No. 11. R. C. Roberts, USA

569. **Seifert, H. S., and Altman, D., A comparison of adiabatic and isothermal expansion processes in rocket nozzles,** *J. Amer. Rocket Soc.* **22,** 3, 159–162, May-June 1952.

An investigation is made of the expansion of gases through a nozzle under isothermal conditions to explore its practical possibilities. It is shown that, if the heat is continuously supplied to maintain constant temperature, the sum of free energy and kinetic energy of gases will remain constant. A consequence of this is that, for ideal gases, there will be no theoretical limit to the exhaust velocity for an isothermal nozzle, and performance parameters are independent of the ratio of specific heats. To compare such a nozzle with that in which the gas expands adiabatically, formulas for isothermal exhaust velocity, mass flow, and thrust coefficient are derived. Y. H. Kuo, USA

570. **Prim, R. C., 3rd, Steady rotational flow of ideal gases,** *J. rational Mech. Analysis* **1,** 3, 425–497, 1952.

Paper concerns flow with vorticity and entropy gradients of inviscid, thermally nonconducting gas with, often, a very general equation of state. Author collects material of many earlier papers (including AMR **2,** Revs. 81, 83, 87, 894; **3,** Revs. 521, 1317, 2006) by himself and others, adding new generalizations of, new proofs for, and new details of earlier results. Greatest immediate value of paper, in reviewer's opinion, lies in its providing a coherent, well-digested presentation of the whole body of work by the inverse method published before 1950. Strength and weakness of the inverse method lie in the concentration on exploration of the differential equations, with little regard to boundary conditions of physical problems.

Three main types of questions are explored, the first two being presented separately for plane, axially symmetrically, and truly spatial flows. (1) What flows have certain simple kinematic properties? Answers are largely negative, in the sense that only relatively trivial flows result, but are valuable in saving future investigators fruitless work. (2) Particular, exact solutions of the differential equations are sought by imposing mathematical restrictions on the unknowns. Extensive families of solutions result, often providing models with interesting properties, but few applications have yet been made to physically important problems. (3) A wealth of general, qualitative results have been discovered, which are collected with great clarity in chap. II. They should, in reviewer's opinion, be of great value for all future work in the field. An example is the substitution principle to the effect, roughly, that any flow can be derived from an equivalent, isoenergetic flow (for gases with equation of state of the form $\rho = P(p)S(s)$; see AMR **3,** Rev. 1317) and, indeed, many rotational flows from equivalent, irrotational ones.

R. E. Meyer, England

571. **Costello, G. R., Cummings, R. L., and Sinnette, J. T., Jr., Detailed computational procedure for design of cascade blades with prescribed velocity distributions in compressible potential flows,** *NACA Rep.* 1060, 14 pp., 1952.

Supersedes paper reviewed in AMR **4,** Rev. 3633.

572. **Kawaguti, M., Note on the velocity distribution over an elliptic cylinder submerged in a uniform flow of compressible fluid,** *J. phys. Soc. Japan* **7,** 3, 313–315, May/June 1952.

The exact analytical expression, correct to M^4, for the velocity distribution over an elliptic cylinder which is submerged in a uniform flow of a compressible fluid [see AMR **5,** Rev. 189] is expanded in ascending powers of θ, the eccentric angle of the ellipse, in order to reduce the expression into a more tractable form. Numerical values of coefficients of θ and θ^3 are given for various values of thickness ratio t ranging from 0 to 1.0, and it is shown that the convergency of the M^2-expansion method is very good near the stagnation point. From author's summary

573. **Corrsin, S., Generalization of a problem of Rayleigh,** *Quart. appl. Math.* **10,** 2, 186–189, July 1952.

A particular solution is worked out to give dissipative temperature distribution of the compressible viscous flow set up by an infinite plate suddenly moved at constant velocity in its own plane. The solution is valid for low Mach number, small lateral velocity compared to the velocity of the plate, insulated wall, unit Prandtl number, constant specific heat C_p, and $\mu \sim \lambda \sim T^{3/4}$ where μ, λ, T are viscosity, thermal conductivity, and absolute temperature, respectively. C. T. Wang, USA

574. **van Deemter, J. J., Bernoulli's theorem for viscous fluids,** *Phys. Rev.* (2) **85,** 6, p. 1049, Mar. 1952.

By eliminating the dissipation function between the thermodynamic energy equation and the energy dissipation formula which follows from the momentum equation, the author obtains

$$\frac{\partial}{\partial t}\left[\rho\left(\tfrac{1}{2}\,\mathbf{v}^2 + u\right) - \rho\mathbf{v}\cdot\mathbf{f}\right. + \nabla\cdot\left[\rho\mathbf{v}\left(\tfrac{1}{2}\,\mathbf{v}^2 + u + \frac{p}{\rho}\right) - 2\mu\mathbf{v}\cdot\mathrm{def}\,\mathbf{v} - \lambda\mathbf{v}\nabla\cdot\mathbf{v} + \mathbf{q}\right] = 0$$

where the notations are classical. He states that, for steady flow of a perfect gas, this result can be applied to the theory of the Ranque-Hilsch vortex tube. [The reviewer does not believe that the distinction made by the author between two methods of obtaining Bernoulli theorems is material; the reason the author obtains a basically different result from the reviewer's [see AMR **4,** Rev. 796] is that he uses the principle of conservation of energy, while the reviewer's theorem is purely dynamical. The author's result is virtually the same as Eq. (E'') of A. Vazsonyi [*Quart. appl. Math.* **3,** 29–37, 1945]. C. Truesdell, USA

575. **Linaluoto, V. V., A numerical integration method for calculating the pressure distribution at supersonic speeds for wings with subsonic leading edge at symmetrical flow conditions,** *SAAB Aircr. Co., Linköping, TN* 6, 19 pp., 1952.

By dividing the integration region into a net of small equal areas having sides parallel to the Mach lines, one arrives at a numerical integration method that can be adapted to arbitrary wings. The integration can be performed with a standard calculating machine. The elements of area at the wing's leading edge are calculated by means of special expressions that can be tabulated or presented in graphical form.

From author's summary by H. G. Lew, USA

576. **Dvornichenko, P. V., On the practical calculation of the hydraulic resistance of fast-moving gases with heat transfer** (in Russian), *Zh. tekh. Fiz.* **22,** 5, 836–847, May 1952.

Method is given to calculate final pressure and velocity of a gas in a circular tube, the initial pressure and velocity of which are given. The calculated values derived in this way are compared with experimental data, and satisfactory agreement is found. Results are partly given in graphs.

D. ter Haar, Scotland

577. **Codegone, C., On the work obtainable from a deep-drilled well which yields a compressed gas** (in Italian), *Termotecnica* **6,** 5, 185–188, May 1952.

A one-dimensional vertical flow under the influence of gravity is treated analytically and graphically, taking into account friction and heat losses. Examples are given for natural gas and

water vapor. Reviewer's remark: In the energy equation, the term for heat losses is missing. G. Guderley, USA

Turbulence, Boundary Layer, etc.

(See also Revs. 445, 680)

578. Cope, W. F., Notes and graphs for boundary layer calculations in compressible flow, *Aero. Res. Counc. Lond. curr. Pap.* no. 89, 8 pp.,14 figs., 1952.

Momentum integral analysis is made for compressible flow of gas with Prandtl number unity over insulated flat plate. For laminar boundary layer, the velocity distribution is assumed sinusoidal. For turbulent boundary layer, two types of velocity distribution are treated: (1) Power-law distribution, and (2) log-law distribution. Formulas and charts are given for calculating the skin-friction coefficient and the displacement and momentum thicknesses up to a Mach number of 4.

For the laminar boundary layer, the skin-friction coefficient decreases by 9% as Mach number increases from 0 to 3.16. For the turbulent layer, there is a decrease of approximately 42% as Mach number goes from 0 to 3.0. Ascher H. Shapiro, USA

579. Nigam, S. D., Advancement of fluid over an infinite plate, *Bull. Calcutta math. Soc.* **43,** 4, 149–152, Dec. 1951.

Flow in the boundary layer of a flat plate is analyzed for the case of the fluid suddenly set in motion. Steady flow outside the boundary layer is assumed behind the initial wave. For laminar flow, the equation and solutions are similar to that of Blasius. Author carries solution to second approximation. Turbulent flow is analyzed with assumption that Prandtl's momentum-transfer theory describes sheer distribution. In the paper, mathematics are abbreviated and no reference or explanation is given.

W. D. Baines, Canada

580. Cooke, J. C., On Pohlhausen's method with application to a swirl problem of Taylor, *J. aero. Sci.* **19,** 7, 486–490, July 1952.

Author points out the difficulty of defining the boundary-layer thickness when applying Pohlhausen's method to three-dimensional flow. Here the velocity parallel to the surface has to be split up in two components with two different velocity profiles, and these do not reach the required percentage value of the mainstream components (e.g., 0.995) at the same wall distance. This is shown by an example solved exactly before. Therefore, a swirl problem solved by Sir G. Taylor [AMR **4,** Rev. 1234] is treated again, now assuming different boundary thicknesses in the two directions and satisfying a further boundary condition. The results differ considerably from Taylor's solution. Yet, since there is no physical reason to prefer one way or the other, it is left open which of these results more closely approximates the unknown exact solution. Karl Wieghardt, Germany

581. Dunn, D. W., and Lin, C. C., The stability of the laminar boundary layer in a compressible fluid for the case of three-dimensional disturbances, *J. aero. Sci.* **19,** 7, p. 491, July 1952.

Squire's theorem states that, for incompressible flow, the stability problem for three-dimensional disturbances is equivalent to that for two-dimensional disturbances. This preliminary report indicates that this theorem may be extended to the stability of subsonic compressible boundary-layer flow by the use of a formal transformation together with an order-of-magnitude argument. Authors say that theorem also seems to be true for low supersonic Mach numbers. R. C. Roberts, USA

582. Bouniol, F., and Eichelbrenner, E. A., Calculation of the compressible laminar boundary layer (in French), *Rech. aéro.* no. 28, 17–20, July/Aug. 1952.

Paper discusses method of calculation of flat-plate boundary layer in compressible fluid, using velocity as independent variable. It is claimed that convergence of successive approximation method is very rapid and that results obtained agree closely with those of Crocco. No numerical results are given. Ordinary differential equations for velocity and temperature as functions of boundary-layer variable $\eta \sim yx^{-1/2}$ are obtained, but exhibited only in form of complicated integral relations. At this point, boundary conditions are given incorrectly as $\eta = 1$, rather than $\eta = \infty$. New dependent variable g, related to shear stress but not equal to it, is now introduced, and Blasius equation, with independent variable as the velocity, is obtained, although Sutherland viscosity-temperature relation is used. The correct equation for g is considerably more complicated.

John A. Lewis, USA

583. Burton, R. A., Equations for estimating laminar boundary layer effects, *J. aero. Sci.* **19,** 8, 573–574, Aug. 1952.

The boundary-layer equation is linearized in a rather arbitrary way without physical arguments. Hence, even if results should prove sufficient in some more cases, already existing simple methods would still seem preferable.

Karl Wieghardt, Germany

584. Thwaites, B., On the momentum equation in laminar boundary-layer flow. A new method of uniparametric calculation, *Aero. Res. Counc. Lond. Rep. Mem.* 2587, 9 pp., Dec. 1947, published 1952.

Author discusses velocity profiles $y/\theta = (t, \lambda)$ with the conditions ${}_0\int^1 (2t-1)f\,dt = 1$; $f(0, \lambda) = 0$; $f(1, \lambda) = \infty$. Here y is distance from surface, θ momentum thickness, $\lambda = \lambda(x)$ = parameter, x coordinate along the surface, $t = u/U$, u velocity at the edge of the boundary layer. By the first condition, θ is independent of the choice of f. By choosing these profiles, calculations are much simpler than when using Pohlhausen's method; Pohlhausen's difficulties for $\lambda > 12$ are avoided. Two special cases are considered.

(a) $f = (1-\lambda)f_1(t) + \lambda f_2(t)$ in which $f_i (i = 1;\ 2)$ fulfils ${}_0\int^1 (2t-1)f_i\,dt = 1$. These profiles are used, if velocity profiles at two different x-values are known. Then the momentum equation can be speedily solved by a step-by-step method. The equation, however, contains 1st and 2nd derivate of U.

(b) $f = B(t)\left\{1 - {}_0\int^1 (2t-1)G(t, \lambda)\,dt + G(t, \lambda)\right\}$, which profile can be used if separation occurs.

Here $B(t)$ represents Blasius' distribution. By choosing $G(t, \lambda) = (C/\lambda)\left\{(\Lambda^2 - \lambda^2 t)^{1/2} - \Lambda\right\}$ with $\Lambda = (1-\lambda^2)/2$, separation occurs for $\lambda = 1$ and Blasius' profile for $\lambda = 0$. $C = 5.1$ is proposed as an approximate value; for more accurate (though cumbersome) calculations, C can be used as a second parameter equation to fulfil the energy equation.

H. Wijker, Holland

585. Bertram, M. H., An approximate method for determining the displacement effects and viscous drag of laminar boundary layers in two-dimensional hypersonic flow, *NACA TN* 2773, 41 pp., Sept. 1952.

A momentum-integral calculation of the laminar boundary layer for an adiabatic wall is made, using a linear velocity profile. The resulting displacement thickness is used to "correct" the potential flow outside the boundary layer. Surface pressure distributions and local skin-friction coefficients are given. Data obtained at $M = 6.86$ in the Langley 11-in. tunnel for flat plates and

a circular arc profile indicate fair agreement with the theoretical predictions. However, the theoretical analysis seems to have been improved upon in the paper by L. Lees and R. F. Probstein, "Hypersonic viscous flow over a flat plate" [*Princeton Univ. Aero. Engr. Lab. Rep.* 195, April 20, 1952].

S. A. Schaaf, USA

586. **Morduchow, M., and Clarke, J. H., Method for calculation of compressible laminar boundary-layer characteristics in axial pressure gradient with zero heat transfer,** *NACA TN* 2784, 43 pp., Sept. 1952.

Method allows rapid calculation of boundary-layer characteristics, including separation and critical Reynolds number. A modified von Kármán-Pohlhausen method is used. Assumptions are: Prandtl number equals unity, polynomials of sixth or seventh degree for velocity profile are used, the viscosity coefficient is directly proportional to the absolute temperature. Solution of differential equation is reduced to evaluating a simple integral. Near separation point a velocity profile is used whose fourth derivate at the wall vanishes. Comparison with known accurate solutions for flow near separation is very good. Examples calculated show earlier separation with increasing Mach number and destabilizing effect of Mach number on boundary layer.

H. Schuh, Sweden

587. **Gazley, C., Jr., Boundary-layer stability and transition in subsonic and supersonic flow; a review of available information with new data in the supersonic range,** Heat Transf. Fluid Mech. Inst., Stanford Univ. Press, 73–93, 1952. $4.

Article contains useful collection of references and results on transition from laminar to turbulent flow in boundary layer. Data on effects of free-stream turbulence, surface curvature, pressure gradient, surface roughness, surface temperature, and compressibility are summarized. Reviewer found some statements a bit deceptive; e.g., (a) that Schubauer-Skramstad measurements [*J. Res. nat. Bur. Stands.* **38,** 1947] "resolved" the "apparent differences" between Taylor's local separation theory of transition and the Tollmien-Schlichting theory of laminar stability. Theories deal with different things; (b) that ranges of damping and amplification predicted by Tollmien-Schlichting were "closely confirmed" by these experiments. Agreement was good in some places and poor in others; (c) the "60-fold" ratio between transition Reynolds number and theoretical and experimental minimum critical Reynolds number is in R_x; it looks smaller in terms of the proper variable R_θ. On this point, one footnote says that R_x is "without significance in flows with pressure gradient," failing to mention that R_θ is appropriate for all other cases as well.

Stanley Corrsin, USA

588. **Slack, E. G., Experimental investigation of heat transfer through laminar and turbulent boundary layers on a cooled flat plate at a Mach number of 2.4,** *NACA TN* 2686, 31 pp., Apr. 1952.

Experimental results for local heat-transfer coefficients and recovery factors for airflow over a cooled flat plate are presented. These data for a Mach number of 2.4 cover a Reynolds number range of 1.5×10^5 to 3×10^6, extending from well into the laminar flow region through transition and slightly into the region of turbulent boundary-layer behavior.

Test techniques used were somewhat indirect in that (1) a number of calibrated heat meters were employed to evaluate the heat-flux distribution over the surface; (2) surface temperatures were deduced from interim temperatures from close to the surface and a correction applied from the heat-meter readings for the surface to interior temperature difference; (3) adiabatic wall temperatures were deduced by extrapolation of a plot of heat flux versus temperature difference, surface to fluid, to the condition of zero heat flux; (4) negative temperature gradients in the flow direction existed over the plate surface so that the theoretical treatment of Chapman and Rubesin [see AMR **3,** Rev. 2732] had to be employed to predict isothermal plate characteristics.

Important conclusions reached are: (1) Temperature recovery factors for laminar and turbulent flow agree well with previous results. For transition flow, however ($1 \times 10^6 < Re < 2 \times 10^6$), considerable scatter is evident, with magnitudes as high as 0.97–0.98 noted. (2) After adjustment of the test results to the uniform surface temperature case, reasonable agreement is reached with theoretical results except for about half the data points, which were obtained from the surface close to leading edge.

Reviewer believes that these results provide some support for the predictions from boundary-layer theory, but can hardly be considered as definitive in view of the indirect test methods used.

A. L. London, USA

589. **Mattioli, E., Statistical theory of turbulence** (in Italian), *Aerotecnica* **32,** 1, 2; 25–42, 87–98; Feb., Apr. 1952.

Paper is a careful summary of the main results of Taylor, von Kármán-Howarth, Kolmogoroff (through the presentation of Batchelor), and of Heisenberg. The order is historical, each fundamental paper being closely followed. Reviewer would prefer a more unified treatment.

A. Craya, France

590. **Gregory, N., Note on Sir Geoffrey Taylor's criterion for the rate of boundary-layer suction at a velocity discontinuity,** *Aero. Res. Counc. Lond. Rep. Mem.* 2496, 12 pp., May 1947, published 1952.

The experimental velocity and static-pressure traverses through the boundary layer near the discontinuity of a Griffith suction wing can be predicted from one experimental velocity profile by means of a modified form of Taylor's criterion that takes account of the effects of the measured curvature of the surface. It is shown that the different effects of curvature act in opposite directions, so that the minimum suction quantity is, in practice, approximately given by the simple form of the theory which assumes no curvature.

Walter Wuest, Germany

591. **Szablewski, W., On the theory of turbulent flow of gases with greatly variable density** (in German), *Ing.-Arch.* **20,** 2, 67–72, 1952.

For the investigation of turbulent mixing phenomena with strong density variation, author proposes a set of equations based on generalization of Reynolds' and Prandtl's hypotheses. For constant pressure fields, the equations of conservation of mass, momentum, energy, and concentration are written, using time averages. By expressing the flow variables as sums of the time averages and the fluctuations, the expressions in the various equations are computed and their order of magnitude investigated. The equations are then written in their developed form and the small order of magnitude terms neglected. Next, the Prandtl mixing-length theory is discussed and the expressions for turbulent mass-flow, shear, heat transfer, and exchange are given in their standard form. Then, the corresponding expressions are derived for fields of strong density variation. Also, the expressions for turbulent exchange of mass, shear, heat transfer, and diffusion are given. It is shown that these reduce to those of Prandtl for constant density fields.

T. P. Torda, USA

592. **Rotta, J., Distribution of shear stresses and energy dissipation in turbulent boundary layers** (in German), *Ing.-Arch.* **20, 3,** 195–207, 1952.

Author assumes that velocity profile in a turbulent boundary

layer with pressure gradient can be represented by a one-parameter family of curves; and to each velocity profile belongs a shear distribution, containing the same form parameter A and a constant α. With these assumptions, quantities such as total dissipation, turbulent energy, etc., can be expressed as functions of A and α. By means of momentum and energy integrals, the constant α can be calculated in terms of quantities such as velocities in the boundary layer and in the potential field, wall shear, etc. In the case of wedge flow, α is calculated from these measured quantities.

For two different α thus determined empirically (according to the boundary conditions applied to shear at the edge of boundary layer), two curves for dissipation against the form parameter A are obtained, and both lie within the range of experimental scatter for relatively small values of A. It appears that this theory gives good approximation for weak pressure gradients.

Y. H. Kuo, USA

593. Donaldson, C. duP., Skin friction and heat transfer through turbulent boundary layers for incompressible and compressible flows, Heat Transf. Fluid Mech. Inst., Stanford Univ. Press, 19–36, 1952.

Paper gives a simple approach to the extension of the incompressible heat-transfer and skin-friction laws to the compressible case. For this purpose, a model of turbulent boundary layer is introduced, dividing the velocity profile sharply into a completely laminar sublayer and a fully turbulent region. It is assumed that the turbulent region has a power-law velocity profile. The thickness of the laminar sublayer is determined by the distance normal to surface where the ratio of the total shearing stress to the viscous stress is given by some definitive ratio. The result of the analysis is proved by comparisons with experimental data and theoretical results of other authors.

Julius Rotta, Germany

Aerodynamics of Flight; Wind Forces

(See also Revs. 447, 502, 539, 560, 565, 610, 612, 630)

594. Kelley, H. J., Prediction of yawing stability characteristics of airplanes during catapulting, *J. aero. Sci.* **19,** 8, 529–539, Aug. 1952.

Paper gives results of theoretical study of yawing behavior of airplane during catapulting. For freely castering nose or tail wheel, solutions are obtained in terms of power series. For nonlinear case of locked nose or tail wheel, solutions are obtained by a finite difference procedure. Using simplifying assumptions, a stability criterion is developed. Paper is mostly concerned with single-pendant towing systems, but V-bridle is also considered. Comparison is shown between calculations and model test data, indicating generally satisfactory agreement.

From author's summary by H. Luskin, USA

595. Crim, A. D., and Hazen, M. E., Normal accelerations and operating conditions encountered by a helicopter in air-mail operations, *NACA TN* 2714, 17 pp., June 1952.

An analysis is presented of the normal accelerations and operating conditions encountered by a single-rotor helicopter engaged in air-mail operations in the vicinity of Los Angeles and its suburbs. Data were obtained from 14 months of operation.

Results indicate that, for this type of operation, maneuver loads developed in routine flight are often greater than the largest gust loads. Considering the maximum positive and negative acceleration increments reached in each flight, approximately 54% of these maximums were due to maneuvers occurring either at take-off or during the landing descent.

The largest enroute accelerations, due to gusts or maneuvers, are similar in magnitude to the landing-descent maneuver loads. Maximum increments recorded enroute were **0.70g** and **−0.60g**, while corresponding values for the descent were **0.60g** and **−0.55g**.

From authors' summary

596. Press, H., An approach to the prediction of the frequency distribution of gust loads on airplanes in normal operations, *NACA TN* 2660, 34 pp., Apr. 1952.

As a basis for the prediction of the gust-load history of airplanes in service operations, the statistical concepts of random variables and probability distributions are applied to the "sharp-edge-gust" formula. Expressions are derived for the frequency distribution of gust loads in terms of distributions of the related variables, such as effective gust, velocity, and air speed. Solutions are obtained under assumptions that appear reasonable on the basis of present practices in gust research. The results are applied in an example, and the predicted load experience is compared with the available flight-loads data for this case.

From author's summary by M. D. Schwartz, USA

597. Prescott, T. W., A theoretical investigation into the lateral stability of an aeroplane controlled by an automatic pilot, with particular reference to the effect of flight path angle, *Aero. Res. Counc. Lond. Rep. Mem.* 2640, 11 pp., Jan. 1948, published 1952.

Paper points out that the usual roll pick-off indication used in autopilot control contains an element proportional to aircraft yawing motion; and the proportionality factor involved depends on the flight-path angle (more accurately the pitch angle) with the horizontal. Consequently, the presence of an adverse yaw term due to aileron position ($-N_\xi$) in the lateral stability equations may give rise to poor damping or instability which is emphasized by pitch attitude of airplane. Controlled airplane may then be stabilized in conventional manner by utilizing rate of yaw correction or appropriately cross-coupling aileron and rudder. Latter will also aid in making coordinated turn.

Paper is of value in indicating that instabilities may arise from gyrocoupling of the three airplane axes, but numerical results are questionable since assumed control laws are not realizable from practical autopilot.

Leonard Becker, USA

598. Robinson, A., Aerofoil theory for swallow-tail wings of small aspect ratio, *Aero. Quart.* 4, part 1, 69–82, Aug. 1952.

Modified version of paper reviewed in AMR **4,** Rev. 2127.

599. Thwaites, B., On the design of aerofoils for which the lift is independent of the incidence, *Aero. Res. Counc. Lond. Rep. Mem.* 2612, 14 pp., 5 figs., Jan. 1947, published 1952.

Paper is concerned principally with developing methods of calculating airfoils using the Thwaites flap [AMR **1,** Rev. 883] in combination with boundary-layer removal from areas where large adverse pressure gradients occur. An exact theory based on the method of Lighthill [*Rep. and Mem.* 2112, April 1945], and an approximate theory following Goldstein's approximations [*Aero. Res. Counc.* 5804 (to be published)] using Theodorsen's transformation of an airfoil into a circle are developed. Both the "normal" and "inverse" airfoil problems are treated. It is indicated that noninclined symmetrical airfoils may be designed to operate over large ranges of lift while maintaining relatively low local velocities, which result implies high critical Mach numbers. The center of pressure is located at the midchord point, which result may invite the application of such airfoils to supersonic aircraft. Reviewer is impressed by the design procedure set forth, and believes airfoils incorporating the Thwaites flap are sufficiently promising to warrant further investigation.

A. J. Eggers, Jr., USA

600. **Riebe, J. M., and Naeseth, R. L., Aerodynamic characteristics of a refined deep-step planing-tail flying-boat hull with various forebody and afterbody shapes,** *NACA TN* 2489, 48 pp., June 1952.

An investigation was made to determine the aerodynamic characteristics of a refined deep-step planing-tail hull with various forebody and afterbody shapes. For comparison, tests were made on a streamline body simulating the fuselage of a modern transport airplane.

The results of the tests, which include the interference effects of a 21%-thick support wing, indicated that, for corresponding configurations, the hull models incorporating a forebody with a length-beam ratio of 7 had lower minimum drag coefficients than the hull models incorporating a forebody with a length-beam ratio of 5. The lowest minimum drag coefficients, 0.0024 and 0.0023, which were considerably less than that of a comparable conventional hull of length-beam ratio 9, were obtained on the length-beam-ratio 7 forebody, alone and with round center boom, respectively. The streamline body had a minimum drag coefficient of 0.0025; flying-boat hulls can, therefore, have drag values comparable to landplane fuselages. The hull angle of attack for minimum drag varied from 2 to 4°.

Longitudinal and lateral stability were generally about the same for all hull models tested and about the same as those of a conventional hull. From authors' summary

601. **Riebe, J. M., and Naeseth, R. L., Aerodynamic characteristics of three deep-step planing-tail flying-boat hulls and a transverse-step hull with extended afterbody,** *NACA TN* 2762, 28 pp., Aug. 1952.

An investigation was made to determine the aerodynamic characteristics in the presence of a wing of three deep-step planing-tail flying-boat hulls which differed only in the amount of step fairing. The hulls were derived by increasing the unfaired-step depth of a planing-tail hull of a previous aerodynamic investigation to a depth of about 92% of the hull beam. For the purpose of comparison, tests were also made of a transverse-step hull with an extended afterbody.

The investigation indicated that the transverse-step hull with extended afterbody had about the same minimum drag coefficient, 0.0066, as a conventional hull, and an angle-of-attack range for minimum drag of 3 to 5°. The hull with a deep unfaired step had a minimum drag coefficient of 0.0057, which was 14% less than the transverse-step hull with extended afterbody; the hulls with step fairing had up to 44% less minimum drag coefficient than the transverse-step hull. Longitudinal and lateral instability varied little with step fairing and were about the same as for a conventional hull. From authors' summary

602. **Lyons, D. J., An examination of the technique of the measurement of the longitudinal manoeuvring characteristics of an aeroplane, and a proposal for a standarised method,** *Aero. Res. Counc. Lond. Rep. Mem.* 2597, 33 pp., Sept. 1947, published 1952.

Author concludes that the "steady stick force per g" as defined in *Rep. and Mem.* 2027 [see AMR **3,** Rev. 343] is the best criterion for the measurement of the maneuverability of an aircraft. It indicates the minimum stick force that has to be exerted by the pilot to break the aircraft, and its value is obtainable in flight by a perfectly definite test procedure. These assertions are justified by comparison of predicted values with flight-test results on a Mosquito and a Lancaster airplane, which show good agreement. It is further concluded that some additional criteria may be necessary to insure that unduly heavy forces are not encountered during sharp pull-outs. A method of measuring the steady-stick force per g, developed by the Royal Aircraft Establishment, is described, and it is suggested that it should be standardized for such tests. Guy L. Bryan, USA

603. **Falkner, V. M., Calculated aerodynamic characteristics of two infinite wings with constant chord,** *Aero. Res. Counc. Lond. Rep. Mem.* 2594, 10 pp., May 1947, published 1952.

Solutions are obtained by the vortex lattice method for the aerodynamic loading of two infinite wings of constant chord with sweepback of 45°, one with a V-joint at the center, the other rounded off with arcs of radius four times the chord. The object is to find the effect on wing loading of sudden changes in direction of the leading or trailing edge. The V-wing shows a reduction in circulation near the joint with accompanying backward movement of the local center of pressure, while the rounded wing has increased circulation without appreciable variation of the center of pressure from the 0.25-chord position.

Author does not know the accuracy of the approximate solutions used in paper, but he believes they are good practical approximations to the accurate answer.

From author's summary by S. I. Pai, USA

604. **Falkner, V. M., and Watson, E. J., Tables of Multhopp and other functions for use in lifting-line and lifting-plane theory,** *Aero. Res. Counc. Lond. Rep. Mem.* 2593, 52 pp., Feb. 1948, published 1952.

In lifting-line theory, difficulties arise in calculating spanwise loading functions for discontinuous downwash if limited terms of a finite Fourier series are used. Special functions are required to deal with discontinuities. Paper gives two classes of these functions, Multhopp functions associated with spanwise discontinuities in induced downwash, and a second with discontinuities of rate of change of downwash in spanwise direction (polygonal representation of induced downwash). Both classes of functions have each been calculated over the semispan for four cases: Center flaps, tip flaps, center ailerons, and tip ailerons, with an accuracy to five decimal places. Examples are given of combination of functions to produce given curves of induced downwash. It can be assumed that functions tabulated will be sufficient to cover almost any problem in wing loading.

Authors deduce that functions should be equally suitable for lifting-plane theory by considering connection between lifting-line and lifting-plane theory through application of Munk's stagger theorem to calculation of induced drag.

F. Keune, Sweden

605. **Flax, A. H., and Lawrence, H. R., The aerodynamics of low-aspect-ratio wings and wing-body combinations,** 3rd Anglo-Amer. aero. Conf., Brighton, Sept. 4–7, 1951, London, Roy. aero. Soc., 363–398.

This clearly written and well-documented paper considers in detail two principal problems: (1) To develop suitable approximations to linear lifting-surface theory for a certain class of wings of low aspect ratio; and (2) to present a method for calculating the nonlinear variation with angle of attack which the experimental curves for lift and pitching moment of such wings show. (Brief extension of the analysis is also made to wing-body combinations.)

The results given by the proposed linear theory for the lift, moment, and pressure distribution for delta and rectangular wings are in fair agreement with those of experiment.

The theory for determining the nonlinear effects is semi-empirical. For the most part, the nonlinear variations are accounted for by merely adding to linear lifting-surface theory the effects of viscous cross flow in planes transverse to the wing's fore

and aft axis. Although this treatment of the nonlinear effects does not appear to be justifiable in general, predictions obtained for the lift and moment on delta and rectangular wings show good agreement with the results of experiment.

Paul F. Byrd, USA

606. **Smirnov, A. I., On the determination of the circulation and lifting force of an arbitrary thin wing located near a wall** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **9**, 45–56, 1951.

Thin-wing theory has been applied to the flow past an infinite wing of small curvature and its mirror image with respect to a plane wall. The boundary condition at the airfoil yields an integral equation

$$2\pi V_\infty \sin \alpha_{sk} + {}_0\int^b I(x, \bar{x}, x_k)\gamma(x)(x - x_k)^{-1}dx = 0 \qquad [*]$$

for the vortex strength $\gamma(x)$ at $(x, 0)$ on the chord, where $(0, 0)$ is at the leading edge, $(b, 0)$ at the trailing edge, α_{sk} is the local angle of attack at $(x_k, 0)$, and $I(x, \bar{x}, x_k)$ is an easily determined function of x_k, x, and the mirror image $(\bar{x}, \bar{y})$ of $(x, 0)$ with respect to the wall. The author sets $\gamma(x)I(x, x, x_k)/2V_\infty = B_{k0} \cot \frac{1}{2}\theta + \Sigma_1^m B_{kn} \sin n\theta$, and $\gamma(x)/2V_\infty = A_0 \cot \frac{1}{2}\theta + \Sigma_1^m A_n \sin n\theta$, where $x = \frac{1}{2}b(1 - \cos\theta)$. Then for $\theta_k = k\pi/(m + 1)$, $0 \leqq k \leqq m$, [*] is imposed at $x_k = x(\theta_k)$ to obtain $m + 1$ linear equations for A_0, $\gamma(x_k)$, from which the circulation $\Gamma = bV_\infty(A_0 + \frac{1}{2}A_1)\sin\alpha$ can be found. In calculating the lift $Y = \rho_0 \int^b V\gamma(x)dx$, V must be taken to be the component of velocity at $(x, 0)$ parallel to the wall of the resultant of the velocity V_∞ of the main flow and the velocity induced by the image airfoil. For lift computation, author replaces the vortex distribution $\gamma(x)$ by discrete vortexes of strength

$$\Gamma_k = {}_{xk}\int^{xk+1} \gamma(x)dx \text{ at } x_k = (k - \tfrac{1}{4})b/\nu,\ 1 \leqq k \leqq \nu,\ x_{\nu+1} = b$$

and $-\Gamma_k$ at their images. His computations with $m = 3$ and $\nu = 1$ for a flat plate lead to excellent agreement with exact values of Γ and Y as functions of angle of attack α and relative distance H/b from the wall. Γ and Y have also been computed for circular-arc airfoils as functions of curvature, α, and H/b. Finally, for $\alpha \leqq 10°$, close agreement has been found between calculated and experimental lift coefficients for symmetrically mounted pairs of NACA four-digit series airfoils.

Courtesy of Mathematical Reviews J. H. Giese, USA

607. **Kelly, L., Optimum climb technique for a jet propelled aircraft,** *Coll. Aero. Cranfield Rep.* no. 57, 38 pp., 12 figs., Apr. 1952.

Optimum climb paths for jet-propelled aircraft are considered, including effects of kinetic energy variation with height. Numerical examples based on a hypothetical high-speed fighter are worked out for several tactical situations. A substantial improvement in time to climb to high altitude is obtained by a flight path consisting of a steady climb at high speed, followed by a "zooming" climb with loss of speed. A. H. Flax, USA

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 362, 533, 534)

608. **Reismann, H., and Best, G. C., Two-dimensional transient motion and flutter of a wing having four degrees of freedom,** *J. aero. Sci.* **19**, 8, 540–542, Aug. 1952.

By expressing the aerodynamic forces corresponding to an arbitrary transient motion in terms of the lift-deficiency function, which next is replaced by its usual approximation of two exponential terms, authors succeed in establishing a set of six linear ordinary differential equations of the second order, determining the transient motion of a wing-aileron-tab combination with four degrees of freedom. This set of equations is particularly amenable to solution by electronic-analog computation.

A. I. van de Vooren, Holland

609. **Radok, J. R. M., Aileron reversal and divergence of swept wings with special consideration of the relevant aerodynamic and elastic characteristics,** *Coll. Aero. Cranfield Rep.* no. 55, 28 pp., 7 figs., Mar. 1952.

Using oblique coordinates, author presents a new approach, as far as structural representation is concerned, to the "static" problems of aeroelasticity (i.e., aileron reversal and divergence) for swept wings. The analytical representation of the problem makes use of integral equations which are shown to be easily rewritten in the form of matrix equations if the complexity of the problem should demand it. In either case, an iteration method may be used to solve the problem.

The theory has been applied to a simple swept wing, and its divergence speed is obtained. In two appendixes, methods are deduced for estimating the aerodynamic derivatives and calculating the elastic influence functions from experimental data. Both methods are applied to a model wing, and the influence functions obtained are compared with their theoretical values.

James E. Martin, USA

610. **Diederich, F. W., Calculation of the lateral control of swept and unswept flexible wings of arbitrary stiffness,** *NACA Rep.* 1024, 19 pp., 1951.

A matrix method similar to that of *NACA Rep.* 1000 is given for determining the effectiveness and reversal speed of lateral controls as well as the aerodynamic loading and the rolling moment due to aileron deflection on swept and unswept wings with arbitrary distribution of stiffness. All deformations and angles of attack are assumed small, and it is also assumed that the wing deformations are known in terms of structural influence coefficients or can be calculated from simple beam theory. Since suitable aerodynamic influence coefficients are not yet available, a modified strip theory is used to determine the antisymmetric lift distribution.

Computing forms and an illustrative example are given, and the general effects of sweep on the aileron reversal speed are deduced. It is shown that the aileron reversal speed decreases with both sweepback and sweepforward, and that the effectiveness of conventional ailerons is relatively low for swept wings at all speeds and for all wing planforms at supersonic speeds.

A. W. Babister, Scotland

611. **Dugundji, J., A Nyquist approach to flutter,** *J. aero. Sci.* **19**, 6, 422–423, June 1952.

A method of applying stability criteria to flutter analysis is presented. For convenience, the method is developed using, as an example, simple bending-torsion-type flutter with two degrees of freedom. The equations are written in terms of arbitrary motion, making use of approximation for the Wagner function so that the Laplace transform may be used. The determinant is then expanded, resulting in a polynomial in the Laplace operator p. In expanding the determinant, the coefficients which are functions of $C(p)$ are left in undetermined form, but it is noted that both the approximation and the exact $C(p)$ have no poles in the positive real half of the complex plane, and hence do not contribute to any instability. The conditions for stability of the polynomial are then examined, and Nyquist-type plots suggested as a means for establishing stability or instability. Nyquist plots for three speeds for a two-degree-of-freedom system are presented. The

results show good correlation with those calculated by the standard AMC method. It is stated that the Nyquist method is convenient when there are many degrees of freedom or in synthesizing servo systems where aeroelastic characteristics play a part.

J. E. Stevens, USA

612. **van de Vooren, A. I., and Yff, J., The effect of aerodynamic lag on the snaking motion of aeroplanes,** *Nat. LuchtLab. Amsterdam Rap.* F. 107, 25 pp., Mar. 1952.

Introduction of time-lag effects into stability derivatives encounters difficulties due to lack of correlation between quasisteady theoretical and experimental values, so that direct use of theoretical (hardly any experimental values being available) unsteady derivatives is not admissible. Authors overcome this difficulty by using essentially ratios of quasisteady and unsteady theoretical values as correction factors (K) to be applied to measured quasisteady values. These factors were found to be almost independent control-surface geometry, and they are given in the form of graphs permitting immediate conversion of quasisteady measured derivatives. Use of these factors causes slight (hence unimportant) increase of snaking region and shows that an undamped harmonic motion may occur when rudder is fixed.

J. R. M. Radok, Australia

613. **Chopin, S., Effect of various parameters on the critical flutter speed of airplanes** (in French), *Rech. aéro.* no. 26, 41–46, Mar./Apr. 1952.

Paper gives in graphical form the results of numerous calculations of flutter speed arranged to show dependence upon altitude, natural frequencies and nodal line positions, degree of mass balance, and rigidity of controls. Value of paper would be greater if details of aircraft used in the calculations had been given.

W. S. Hemp, England

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 639, 649, 667)

614. **Fabri, J., and Siestrunck, R., Study of the supersonic propeller** (in French), *Actes Coll. inter. Mécan.* **I,** *Publ. sci. tech. Min. Air, Paris,* no. 248, 113–130, 1951.

Authors write the expression of the propulsive efficiency of a turboprop and conclude that, for the flight speed near the sonic speed, the application of the supersonic propeller is useful when the propulsive efficiency of the propeller is not lower than 0.7. Authors attempt to show that it is really possible to obtain this efficiency; the propeller characteristics are calculated by the method of the "representative section" assuming (a) for the velocities induced by the free vortex, the same expressions available for a propeller with an infinite number of blades in incompressible flow; (b) for the lift and drag coefficients of the profiles, the same formula available in the two-dimensional supersonic flow. The results are corrected, taking into account the interference of the blade elements and the loss of lift at the tips; the method followed for these corrections is very rough and allows one to obtain only the order of magnitude of the corrections.

Carlo Ferrari, Italy

615. **Kearton, W. J., and Keh, T. H., Leakage of air through labyrinth glands of staggered type,** *Instn. mech. Engrs.* **166, 2,** 180–188, Proc. (A) 1952.

A theory is given for the air flow through labyrinth gland consisting of a series of constrictions of equal area of opening. Theory follows well-known method of treatment with certain simplifying assumptions. Critical pressure ratio is obtained by taking the contraction coefficient of the last stage as different from those of the other stages, which are assumed to be equal. Values of discharge coefficient as function of pressure ratio are determined experimentally, using approximate formula for evaluation. No mention is made of theoretical change of contraction coefficient due to compressibility effect.

L. S. Dzung, Switzerland

616. **Voit, C. H., and Thomson, A. R., An analytical investigation using aerodynamic limitations of several designs of high stage pressure ratio multistage compressors,** *NACA TN* 2589, 56 pp., Dec. 1951.

The weight flow, total pressure rise, and tip speed are calculated for stages suitable for use in aircraft compressors with limits on Mach number, deflection, lift coefficient, and the ratio of static pressure ratio across a blade row to the entering axial dynamic head. For stages with constant work done at all radii, it is shown that wheel-type rotation entering the stage, plus a vortex added in the rotor, gives better results than the use of symmetrical velocity diagrams at all radii, provided that the symmetrical velocity diagram of the first type of stage is put at the correct radius. The analysis, which contains a number of simplifying assumptions, is then extended to a multistage compressor for which typical inlet, intermediate, and final stages of the first type are examined. It is shown that careful choice of inlet-flow angle relative to blades at tip of the rotor is necessary to obtain high pressure ratios per stage. The effect of limiting the static pressure rise across a row of blades, in order to avoid thickening of the boundary layer on the walls of the annulus, is shown to be marked. Comparison between the stage-by-stage design of a typical compressor shows the advantage of this procedure compared with a number of others in which choice of optimum flow angles for each group of stages is not made. Although the various numerical values assumed for limiting Mach numbers, etc., may be arguable—they were based on some unpublished cascade data by Bogdonoff and some single-stage experiments—the conclusions, of which there are many, are generally interesting. It is, however, doubtful whether the authors are justified in assuming that the limiting value of the pressure-rise parameter should be the same for both rotors and stators.

W. R. Hawthorne, England

617. **Fontaine, E., and Campmas, P., On the separation of losses in Francis turbines** (in French), *Houille blanche* **7,** 2, 269–282, Apr. 1952.

Paper extends former investigations [see AMR **4,** Rev. 3033] in which Poisson's thermometric method was applied to determine over-all efficiency and labyrinth losses in turbines. Tests now reported were made on 30,000-kw vertical shaft units at Brommat, head 240–250 m, specific speed about 100 metric.

Authors separate labyrinth losses into two parts, one the loss of power corresponding to the leakage flow under net head, the other due to viscous friction on the outside of the runner in the labyrinths, and point out that increasing clearances will increase former and reduce latter, and vice versa, but that reduction in diameter of labyrinths reduces both sources of loss.

Leakage flow from upper labyrinth is used at Brommat for cooling purposes and could be measured. Flow through lower labyrinth is deduced, assuming that it varies as the square root of the head. Thermometric measurements enable both parts of labyrinth loss to be determined.

Draft-tube losses were determined by using a Pitot tube traversed radially below runner to measure pressure, velocity, and spiral angle of flow, average total energy being deduced by graphic integration. Authors have assumed axial symmetry but do not appear to have computed flow from velocity measurements as a check.

Principal interest of results is that more than 50% of total losses at normal load are due to labyrinth losses. Authors observe that the efficiency of the casing, guides, and runner is already very high even at part load, and that the gain which could be achieved by the reduction of draft-tube and labyrinth losses justifies further intensive study.

Some errors have been noted. The table of draft-tube measurements at full load gives the wrong direction of rotation. The table of measurements at 25,000 kw is headed $^3/_4$ full load instead of $^5/_6$ full load. One of the curves in Fig. 6 is wrongly labeled. Reviewer also notes that all viscous friction losses on exterior of runner are included in measured labyrinth losses.

Alan Burn, Australia

618. Martyrer, E., On the starting behavior of Föttinger torque converters (in German), *ZVDI* **94**, 5, 127–134, Feb. 1952.

Using momentum and energy equations, the starting behavior of Föttinger torque converters is thoroughly analyzed, first for the case of axial-flow construction and then for the general case of mixed-flow construction. Frictional resistance is neglected, yet its effect could be estimated. The effect of blade arrangements on the performance of torque converters is also studied in detail. Results are presented in graphical form. T. Y. Toong, USA

619. Huntley, S. C., Effect of compressor-outlet air bleed on performance of a centrifugal-flow turbojet engine with a constant-area jet nozzle, *NACA TN* 2713, 20 pp., June 1952.

The effect of compressor-outlet air bleed on a centrifugal-type turbojet with constant-area jet nozzle is calculated, using an analysis based on experimentally determined component characteristics. Ranges of engine speed and air bleed are, respectively, 0.9 to 1.0 and 0 to 0.10 of rated quantities. Flight Mach number is 0.52; altitude is 24,000 ft. At constant engine speed, constant net thrust, or maximum net thrust, each % of air bleed costs about 2% of specific fuel consumption. At constant tail-pipe temperature, each % of air bleed leads to 2.5% loss in max net thrust. At constant engine speed, 0.5% of net thrust is lost for each % of air bleed. Due to difference in compressor characteristics, the losses in an axial-flow turbojet engine with compressor air bleed are somewhat greater. J. G. Slotboom, Holland

620. Seifert, H. S., The effect of variable propellant density on rocket performance, *J. Amer. Rocket Soc.* **22**, 4, 213–215, July-Aug. 1952.

Author arrives at an elementary conclusion by complex analysis. For rocket jet expanding completely and adiabatically into vacuum, the thrust can be increased at constant-volume flow rate by adding high density fluid. H. R. Ivey, USA

621. Louthan, G. W., Hydraulic noise reduction, *Prod. Engng.* **23**, 2, 3, 4; 178–182, 135–139, 182–185; Feb., Mar., Apr. 1952.

Author presents his theory of the origin of pressure waves in the output of piston-type hydraulic oil pumps. He ascribes the waves to the compression of the oil in the cylinders by the high pressure on the outlet side. He takes no consideration of the piston motion as a contributing factor in the generation of these waves. The experimental results give values considerably higher than his theory predicts. To eliminate or reduce intensity of these waves, he examines the attenuating effect of an enlargement in the discharge line. Such a chamber can give considerable improvement, and a design chart is given for determining the chamber volume required.

Entrained air is shown to be important by experimental data. He presents his theory of the effect of entrained air and discusses means for eliminating air and gases. Paper refers to experimental work, of which too little is presented in the text, to substantiate the theory. Dino Morelli, USA

Flow and Flight Test Techniques

(See also Revs. 343, 470, 525)

622. Barish, D. T., Interim report on a study of Mach one wind tunnels, *AF tech. Rep.* 52–88, 29 pp., Apr. 1952.

Paper discusses a theoretical analysis and preliminary experimental work on the simulation in wind tunnels of flows with a sonic free-stream velocity.

The solutions which are valid asymptotically are extended to include higher-order terms so that flow patterns at distances of technical interest from bodies with and without lift can be discussed. This is done with a view toward determining the essential characteristics which streamlines near a wind-tunnel wall would have to possess if the simulation of Mach one flow were to be obtained, and also toward determining which body shape parameters are needed in order to apply the correct scale factors. The results indicate that the ratio of mo lel to tunnel size, where a single parameter is sufficient to give the conditions at the wall, is quite large.

A preliminary set of wind-tunnel tests was made with inclined plane walls in the test section. This approximation of the correct streamline contour yielded data which appear to be in good agreement with the theoretical results at Mach one.

R. C. Binder, USA

623. Thom, A., and Jones, Myra, Tunnel blockage near the choking condition, *Aero. Res. Counc. Lond. Rep. Mem.* 2385, 12 pp., 11 figs., Aug. 1946, published 1952.

This recently published paper reports on a theoretical study of tunnel blockage made in 1946. Mach number corrections for Rankine ovals at speeds up to choking are given. Authors find that correction depends on model-length to tunnel-height ratio, but for small models is independent of thickness-chord ratio. The possibility of shock waves is not taken into account in this theory. Further calculations are made in *Rep. Mem.* 2442.

Wayland Griffith, USA

624. Erdmann, S. F., Experimental investigations in the transonic and supersonic range (in Dutch), *Ingenieur* **64**, 31, L.24–L.28, Aug. 1952.

Elementary survey with a number of illustrative figures.

N. H. Johannesen, England

625. Betchov, R., and Welling, W., Some experiences regarding the nonlinearity of hot wires, *NACA TM* 1223, 13 pp., June 1952.

See AMR **4**, Rev. 2213.

626. Asbeck, W. K., Laiderman, D. D., and Van Loo, M., A high shear method of rating brushability of paints, *J. Colloid Sci.* **7**, 3, 306–315, June 1952.

A rotational viscometer is described which operates in the range of higher shear velocities encountered in the brushing of paints. Because the centering of the inner cylinder is handled automatically, the construction is rather simple, and clearances of 100μ are maintained easily. At these clearances, shear velocities in the order of 20,000 reciprocal seconds are attainable, while at smaller clearances these values may be increased substantially without excessive temperature rise. From authors' summary

627. **Iwanami, S., On the study of technical viscometers,** *Mem. Fac. Technol., Tokyo Metrop. Univ.* no. 2, 31–40, 1952.

In the process of developing a new technical viscometer, author describes his experiments concerning the flow of liquids of different viscosity through pipes, short tubes, and various orifices. Formulas which describe the experimental data are given.

M. S. Macovsky, USA

628. **Agnew, J. T., Line-reversal techniques in the determination of temperature of gun flash or other rapid transient phenomena,** *Trans. ASME* **74,** 3, 333–341, Apr. 1952.

Author describes a technique of measuring the instantaneous temperature of hot gases, using a refinement of a method originally suggested by Fery [*Compte Rendus* **137,** pp. 909–912, 1903]. The image of an incandescent filament is focused at the point where the temperature is to be measured; the image is, in turn, focused on the entrance slit of a spectroscope and the combined spectrum of the filament and a flame in the optical path is observed at the focal plane of the spectroscope. The intensity of a selected wave length, usually that of the sodium D-line, is measured; the flame must contain a supply of the appropriate atoms which absorb and emit at this wave length. The temperature of the filament is adjusted until the intensity of the observed spectrum line is the same in the presence or absence of burning gas in the optical path; this temperature is then the same as the temperature of the flame. The intensity is measured with photosensitive tubes and a cathode-ray oscilloscope.

Some representative temperature measurements are given; differences between temperatures measured, using various wave lengths, are noted and discussed. Few details of the equipment and procedures are included. F. I. Badgley, USA

629. **Hubbard, P. G., Hydrodynamic problems in three dimensions,** *Proc. Amer. Soc. civ. Engrs.* **78,** Separ. no. 143, 9 pp., Aug. 1952.

A scale model of the hydraulic problem is built of Lucite sheets for the walls and copper sheets or gauze for the constant pressure surfaces. It is filled with 0.016 molar copper sulphate solution and a small alternating current passed. The observed voltage gradient is proportional to pressure gradient. A four-decade potentiometer is balanced by a two-tube vacuum-tube voltmeter with an accuracy of 0.01%. Agreement with other methods of solving these problems is to better than 1%. Even if the results are not to be accepted as quantitative, quick and economical preliminary selection of the best design can be carried out, to be followed by test under actual flow conditions.

Results are given of analysis of flow from a reservoir to a square conduit through a square rounded nozzle. The lowest pressure, therefore greatest likelihood of cavitation, was found to be at the top of the end of the nozzle for the particular dimensions. Calculation of velocity and piezometric head is shown.

C. F. Bonilla, USA

630. **Bennett, F. D., Carter, W. C., and Bergdolt, V. E., Interferometric analysis of airflow about projectiles in free flight,** *J. appl. Phys.* **23,** 4, 453–469, Apr. 1952.

Interferograms of cone-cylinder projectiles in free-flight are calculated with the use of the ENIAC computing machine. The integral equation describing the relation between fringe shift and a rotationally symmetric density field is solved for the density, using Abel's method, and is transformed into a difference equation suitable for the ENIAC. Errors connected with this procedure are discussed: Errors are introduced by use of finite differences where density changes discontinuously (shocks); random errors accumulate especially near the axis of the field; no satisfactory treatment of refraction errors is possible at present; yaw of the projectile may cause deviation from axisymmetric flow assumed in evaluation. Interferograms and evaluation in form of isopycnal charts are presented for 15° half angle, cal. 30 cone-cylinder at Mach number 2.7 and 2.16, 30° half angle, cal. 30 cone-cylinder at $M = 1.77$, and cal. 0.25 sphere at $M = 2$, all at atmospheric pressure. Comparisons show generally good agreement with previous measurements in wind tunnels, some deviations from calculated density fields.

E. R. G. Eckert, USA

631. **Brown, F. N. M., An American method of photographing flow patterns,** *Aircr. Engng.* **24,** 280, 164–169, June 1952.

Article describes a successful scheme of smoke-flow visualization, perfected as the result of extensive study of appropriate wind-tunnel and smoke-producing equipment. While the general idea is an old one, the technique has here been refined to the stage of a research tool—not simply the usual demonstration apparatus. Photographic techniques are used, and 30 interesting flow pictures are shown, including wakes, boundary layers, grid turbulence, and tip vortexes. Author finds hints of previously unsuspected phenomena and recommends further investigation.

G. B. Schubauer, USA

632. **Bird, J. D., and Riley, D. R., Some experiments on visualization of flow fields behind low-aspect-ratio wings by means of a tuft grid,** *NACA TN* 2674, 32 pp., May 1952.

A technique for obtaining a physical picture of the flow behind a wing, combination of wings, or other aircraft components is described. This technique involves photographing from far downstream the action of a large number of tufts of uniform length mounted on a screen. This procedure permits obtaining, in an approximate fashion, an important result of a Pitot-yaw-head survey; namely, a vector plot of the flow field in a plane normal to the airstream at a station downstream of an aerodynamic surface. A preliminary examination of the tuft-grid technique as discussed in this paper indicates that quantitative analyses concerning such factors as trailing-vortex strength and location, approximate downwash and sidewash angles over a large field behind lifting surfaces, and other aerodynamic forms may be satisfactorily conducted with the data obtained by this technique.

From authors' summary by G. B. Schubauer, USA

Thermodynamics

(See also Revs. 562, 569, 577, 620, 648, 653)

633. **Fényes, I., Application of mathematical principles of mechanics in thermodynamics** (in German), *Z. Phys.* **132,** 2, 140–145, 1952.

The relationships between the mathematical principles of mechanics and the mathematical principles of classical thermodynamics are generalized and presented in tables. The irreversible process is considered. The limitations as applied to the quantum aspects of thermodynamics are pointed out.

W. L. Sibbitt, USA

634. **Dutta, M., On equation of state of real gases,** *Proc. nat. Inst. Sci. India* **18,** 2, 81–91, 1952.

The equation of state of a gas is calculated by a statistical method involving the division of phase space in cells. The derivation of Boltzmann's second virial coefficient, $5b^2/8v^2$, is criticized, and a corrected value is derived. In reviewer's opinion, author is mistaken in his criticism of Boltzmann's derivation.

H. C. Brinkman, Indonesia

635. Verschaffelt, J. E., On the generalization of the thermic potential (in French), *Acad. roy. Belgique, Bull. Cl. Sci.* (5) **38**, 1–2, 81–88, 1952.

The concept of the thermic potential is generalized, combining it with the concept of potential energy.

From author's summary

636. Aubert-Huetz, Madeleine, A new method for measuring the ratio of specific heats in gases (in French), *C. R. Acad. Sci. Paris* **235**, 2, 141–143, July 1952.

Specific heat ratios are measured, using the method of a self-supporting oscillation of a liquid column in a *U*-shaped tube which is connected at both ends to vessels containing the gas under investigation. Advantages of the method and results for hydrogen are discussed. K. W. Taconis, Holland

637. Rozenfel'd, L. M., Thermodynamic cycles of dynamic heating using the temperature difference of the cold time of the year (in Russian), *Doklady Akad. Nauk SSSR* (*N.S.*) **82**, 3, 393–396, Jan. 1952.

It has been shown previously that the utilization of fuel for performing work to be subsequently spent in a cycle of dynamic heating is more advantageous than burning the fuel directly for that purpose. A system of dynamic heating incorporating an ammonia-absorption refrigeration cycle is discussed and illustrated with a general layout sketch and a T-S diagram. The principle of operation of such a system consists in combination of two cycles—the cycle of a heat engine, and the cycle of dynamic heating. L. M. Tichvinsky, France

638. Egerton, Sir Alfred, and Thabet, S. K., Flame propagation: the measurement of burning velocities of slow flames and the determination of limits of combustion, *Proc. roy. Soc. Lond.* (*A*) **211**, 1107, 445–471, Mar. 1952.

A method of measuring burning velocities of combustible gas/air mixtures near the limits of combustion is developed, using a burner providing a flat disk-shaped flame. The method is applied to methane, propane, N-pentane, N-heptane, ethylene, acetylene, and benzene flames of velocities 5 to 10 cm/s. The characteristics of the burner and the flames are discussed; the time during which unburnt gas can be heated by conduction from the flame appears to be insufficient for purely thermal initiation, and the reactions are, therefore, probably started by diffusion of radicals from the flame front. The burning velocities of these slow flames are mainly dependent on reaction heat, which determines the temperature of the flame and the rate of the reactions. The effect of some additives ($^1/_2\%$ by volume) on the burning velocities in the range investigated and on the lower limits is thermal; no catalytic influence was found.

The flat flame is only stable within a fairly narrow range of velocity; cusped flames are readily formed, particularly with mixtures rather richer in oxygen than upper-limit mixtures.

The flat-flame burner is also applied to the determination of limits of combustion. The lower limits are lower when determined in this manner, compared with the standard tube method. The limit determinations can be carried out easily over a wide range of mixtures. The effect of argon on the limits is consistent with the change in specific heat of the mixture, but carbon dioxide appears to have a further effect.

Reviewer offers these comments on the foregoing paragraphs from the author's summary: (1) P.454. While extrapolation of the temperature effect to determine what the flame speed would have been at room temperatures may be all right, it does not necessarily follow that a stable flame could be obtained at room temperature with the flat-flame burner which would have that flame speed. Therefore, there may be some doubt that limits lower than those determined by the tube method are indicated (p. 465). (2) While it appears, by the author's calculations, that heat conduction may be ruled out as the controlling mechanism of propagation (p. 452), it does not necessarily follow that diffusion of the very low concentration of hydrogen atoms (fig. 7) is controlling. For example, Simon and Wong [*NACA RM* E51H09, Oct. 18, 1951] had to add a constant nondiffusion dependent term to the Tanford-Pease flame-velocity equation in order to predict their experimental values of maximum flame velocity. This constant was of the same order as the limit velocities reported by Egerton and Thabot. (3) A concern of most experimenters is how flat a "flat flame" really is; however, fig. 17b seems to be a good indication that the authors should obtain flat flames with their burner. A. W. Jones, USA

639. Technical data of internal combustion motors of west German motor factories (in German), *Motortech. Z.* **13**, 4, 76–108, Apr. 1952.

640. Huggill, J. A. W., The flow of gases through capillaries, *Proc. roy. Soc. Lond.* (*A*) **212**, 1108, 123–136, Apr. 1952.

The flows of hydrogen, helium, nitrogen, ethylene, argon, and carbon dioxide through capillaries have been measured at room temperature in the region of transition between molecular and viscous flow for capillary walls of polymethylmethacrylate and gold.

The differential flows of the mixtures nitrogen/carbon dioxide, argon/carbon dioxide, and nitrogen/ethylene were determined by measurement of the change of concentration during effusion through similar capillaries. Results are compared with recent theories, and the separation at high pressures due to differing collision diameters is verified.

From author's summary by Myron Tribus, USA

Heat and Mass Transfer

(See also Revs. 328, 333, 545, 548, 683)

641. Verschoor, J. D., and Greebler, P., Heat transfer by gas conduction and radiation in fibrous insulations, *Trans. ASME* **74**, 6, 961–968, Aug. 1952.

See AMR **5**, Rev. 534.

642. Holm, R., Temperature development in a heated contact with application to sliding contacts, *J. appl. Mech.* **19**, 3, 369–374, Sept. 1952.

The calculation of temperature in and around a contact heated by an electric current or friction is of practical importance. The form and size of contact are generally only roughly known, and approximate solutions only are required. Exact solutions for a few special cases have been previously obtained, but these are complex for computational purposes. Satisfactory approximate solutions, relatively simple to work from, are derived by author for cases of circular and oval heat sources, both stationary and moving in face of a semi-infinite solid. Reviewer is of opinion that notation employed is not always well devised.

C. J. Tranter, England

643. Shaposhnikov, I. G., On the theory of weak convection (in Russian), *Zh. tekh. Fiz.* **22**, 5, 826–828, May 1952.

Description, in general terms, of a process of solving, by successive approximations, the system of equations of weak, steady, free-heat convection. The physical problem (as specified by

boundary conditions) appears rather obscure to this reviewer.
A. von Baranoff, France

644. **Zhukhovitskiĭ, E. M., On free stationary convection in an infinite horizontal pipe** (in Russian), *Zh. tekh. Fiz.* **22**, 5, 832–835, May 1952.

Equations of Stokes-Navier with specific gravity changes due to heating and equation of heat flow in fluids [see, e.g., Milne-Thomson, "Theoretical hydrodynamics," 2nd ed., p. 513] are rendered dimensionless by introducing appropriate units for stream function and temperature. Changes of density and viscosity are taken as small. Stream function and temperature are expanded in power series of Grashof number $Gr = g \cdot \beta_0 \cdot A \cdot R^4 / \nu_0^2$ (g is gravity acceleration, β_0 coefficient of thermal expansion, R pipe radius, ν_0 kinematic viscosity) for given horizontal temperature gradient A at infinity. Numerical computations up to the second-order approximation show temperature distribution determined by the product of Prandtl and Grashof numbers. Distribution of the horizontal and vertical components of temperature gradient for a typical case is given. Agreement with experimental data by Ostroumov [*Doklad Akad. Nauk SSSR* **21**, 887, 1950] is generally good. A. Kuhelj, Yugoslavia

645. **Thomaes, G., Studies on thermodiffusion in liquid phase** (in French), *Physica* **17**, 10, 885–898, Oct. 1951.

To calculate the Soret effect for different (benzene) solutions, author uses the optical method of Tanner based on the change of refractive index. Solutions were filled in a chamber pressed between two parallel plates held at a constant difference of temperature (±0.01 C). The experimental curves were evaluated by means of De Groot's differential equations solved for concentrations between 0 and 1. From a solution for stationary case ($t \to \infty$), the Soret effect is calculated. The case $t \to 0$ enables the explanation of the irregular distribution of concentration on plate surfaces. O. Maštovský, Czechoslovakia

646. **Gardner, K. A., Heat-exchanger tube-sheet design—2, Fixed tube sheets,** *J. appl. Mech.* **19**, 2, 159–166, June 1952.

Tube sheet in heat exchanger is analyzed as homogeneous isotropic elastic plate with elastic rotational restraint at edge and continuously varying axially symmetrical lateral load. Flexural stiffness is reduced by constant factor to account for holes in plate. Load intensity on sheet depends linearly on deflection of sheet, by virtue of thermal and elastic strains in tubes and outer shell, and constant fluid pressures on sheet. Solution of differential equation for sheet is expressed in terms of ber and bei functions. Correlation with earlier theory of author for floating-head-type heat exchangers is achieved by modifying pressure on sheet.
H. L. Langhaar, USA

647. **Karush, W., A steady-state heat flow problem for a quarter infinite solid,** *J. appl. Phys.* **23**, 4, 492–494, Apr. 1952.

The steady-state temperature field $T(x,y)$ in a homogeneous solid $x \geq 0$, $y \geq 0$, z arbitrary, is studied when the flow out the face $y = 0$ is a prescribed function $g(x)$. Along the face $x = 0$, either the condition $T = 0$ or $k(\partial T/\partial x) = hT$ is assumed.
From author's summary by H. Wijker, Holland

648. **Böhm, J., Graphic determination of the heat-transfer coefficient of condensed vapor** (in German), *Schweiz. Bauztg.* **70**, 23, 24; 327–330, 344–348; June 1952.

A series of nomographs are given for the rapid estimation of the value of the film coefficient on both tubular surfaces and plane walls. Both laminar and turbulent flow are considered. Data are given for about 29 compounds. A portion of these data is from American literature. Author concludes with an excellent discussion of the factors which influence the film coefficients.
W. L. Sibbitt, USA

649. **Livingood, J. N. B., and Brown, W. B., Analysis of temperature distribution in liquid-cooled turbine blades,** *NACA Rep.* 1066, 21 pp., 1952.

Supersedes paper reviewed in AMR **4**, Rev. 3994.

650. **Weinberg, S., Steam heat transfer to small drops of water,** *Brit. J. appl. Phys.* **2**, 12, 363–366, Dec. 1951.

Heat transfer from saturated atmosphere to small drops of water is treated on an energy-potential basis. The temperature distribution within a small water drop, based upon the assumption of static heat-transfer conditions, is shown to lead to erroneous results. Author presents a more realistic analysis based upon consideration of the energy-exchange processes, and presents a method for the prediction of evaporation rates.
G. Goodwin, USA

651. **Albertson, M. L., Evaporation from a plane boundary,** Heat Transf. Fluid Mech. Inst., Stanford Univ., 243–254, 1951. $5.

The evaporation coefficient C_e is defined as $E/\Delta C_s U x'$, where E is the total rate of evaporation, ΔC_s represents the concentration difference between water surface and free stream, U is the free-stream velocity, and x' equals the distance of the evaporating surface from the upstream edge. An analogy between C_e and the drag coefficient is used in order to obtain functional forms for C_e for laminar and turbulent boundary layers.

Experiments were performed over a hundredfold range in Péclet number S and a tenfold range of x'/x where x is distance from the upstream edge. Observed velocity distributions were found to be in accord with the Blasius relation or the logarithmic law for laminar or turbulent conditions, respectively. For the laminar boundary layer, it was found that $C_e = 0.722\, S^{-(1/2)}(x'/x)^{-0.06}$. No satisfactory correlation for C_e could be obtained for the turbulent boundary layer. All of the experimental data were found to be in accord with the relation $Nu' = 0.5\, B^{4/5}$ where Nu' is the Nusselt number for diffusion of water vapor into air, and the coefficient of evaporation which does not include the ambient velocity; B equals the product of x' and the shear velocity divided by the molecular diffusion coefficient of water vapor.
S. S. Penner, USA

652. **De Nobel, J., Heat conductivity of steels and a few other metals at low temperatures,** *Physica* **17**, 5, 551–562, May 1951.

Heat conductivities of aluminum, iron, nickel, monel metal, and of nickel, manganese, and chromium steels have been investigated at the temperatures of liquid hydrogen and liquid air in the range of 15 to 95 K. The two methods employed to measure heat conductivities are described, and results are given.
W. M. Rohsenow, USA

653. **Mendelssohn, K., and Rosenberg, H. M., The thermal conductivity of metals at low temperatures. I: The elements of groups 1, 2 and 3. II: The transition elements,** *Proc. phys. Soc. Lond.* (*A*) **65**, part 6, 390A, 385–394, June 1952.

The thermal conductivity of Cu, Ag, Au, Mg, Cd, Al, In, and one polycrystalline and two single-crystal specimens of Zn have been measured in the range 2–40 K. Each specimen shows a maximum in the conductivity in this range. The values of the coefficients α and β in the equation for the thermal resistance $R = \alpha T^2 + \beta/T$ have been calculated for each specimen.

The thermal conductivity in the range 2–40 K has been measured for Ti, Mn, Fe, Ni, Zr, Cb, Mo, Rh, Pd, Ta, W, Ir, Pt, U, and for a Pb single crystal. As a rule, the metals of group 8 have a much higher conductivity than have the metals of the earlier groups. The values of α and β in the equation for the thermal resistance $R = \alpha T^2 + \beta/T$ have been calculated for each specimen. The experiments on Cb indicate that the normal state was not reached in a field of 3300 gauss at temperatures below 5 K. From authors' summary

Acoustics

(See also Rev. 621)

654. Lighthill, M. J., On sound generated aerodynamically. I. General theory, *Proc. roy. Soc. Lond.* (*A*) **211,** 1107, 564–587, Mar. 1952.

Paper considers sound as a byproduct of an air flow as distinct from sound produced by the vibration of solids. The air flow may contain fluctuations as a result of instability, giving at low Reynolds numbers a regular eddy pattern, and at high numbers an irregular turbulent motion. All effects requiring the vibration of solid boundaries are excluded, and not classed as aerodynamics.

The initiated theory is based on the equations of motion of a gas, for the purpose of estimating the sound radiated from a fluid flow with rigid boundaries, which, as a result of instability, contains regular fluctuations or turbulence. The sound field is that which would be produced by a static distribution of acoustic quadrupoles whose instantaneous strength per unit volume is $\rho v_i v_j + p_{ij} - a_0^2 \rho \delta_{ij}$ (ρ density, v_i velocity vector, p_{ij} compressive stress tensor, a_0 velocity of sound outside the flow), in many cases approximated by $\rho_0 v_i v_j$. The radiation field is deduced by retarded potential solutions. In it, the intensity depends crucially on the frequency as well as on the strength of the quadrupoles, and, as a result, increases in proportion to a high power, near the 8th, of a typical velocity U in the flow. Physically, the mechanism of conversion of energy from kinetic to acoustic is based on fluctuations in the flow of momentum across fixed surfaces, and it is explained how this accounts both for the relative inefficiency of the process and for the increase of efficiency with U. Furthermore, it is shown how the efficiency is also increased, particularly for the sound emitted forward, in the case of fluctuations convected at a not negligible Mach number.

From author's summary by M. Schaefer, Germany

655. Kronig, R., Thellung, A., and Woldringh, H. H., On the theory of the propagation of sound in He II, *Physica* **18,** 1, 21–32, Jan. 1952.

A previous publication of the first two authors [AMR **4,** Rev. 3715] considered the propagation of first and second sound on the assumption that the transformation of the two fluids into each other was infinitely quick. The present paper generalizes this treatment by assuming that the relaxation time for the transformation of the two fluids into each other is finite. This relaxation adds a damping to the ordinary first sound in addition to that caused by the viscosity. Near the λ-point transformation, the damping may be as much as 10 times as large as that caused by viscosity. From experimental values measured, the relaxation time must be either less than 10^{-12} sec or greater than 10^{-4} sec, with more credence given to the longer time. The theory of the temperature jump at a material boundary for stationary heat flow is discussed on the same basis.

Warren P. Mason, USA

656. Meyer, E., and Oberst, H., Resonance absorbers for water-borne sound (in German), *Akust. Beihefte* **3,** AB149–AB170, 1952.

The resonance absorbers for water-borne sound treated in this paper are smooth rubber sheets, 4 mm thick, which are pasted to steel plates of various thicknesses (ship walls). They contain cylindrical air cavities able to oscillate, the bigger ones of which are sound-absorbing resonators. The number of cavities per unit area can be adapted to the thickness of the steel plate in order to attain the highest possible absorption in the desired frequency range.

Reflection factors below 10%, i.e., absorption factors higher than 99%, have been obtained in the frequency range 9 to 18 kcps. The design of the absorbers and the physical principles underlying the problem are described in detail. Some aspects of the measuring technique and the technology of rubber are mentioned. From authors' summary

657. Morita, S., Sonde method of measuring the ultrasonic field intensity, *J. phys. Soc. Japan* **7,** 2, 214–219, Mar./Apr. 1952.

A small ball (2-mm diam) of sound-absorbing material (as vinyl resins or glass) contains a thermistor of 0.3–0.5-mm diam in its center. The temperature change of the thermistor in the ultrasonic field is measured by an a-c Wheatstone bridge. Sensitivity of the sonde is considerable, being 20 C temperature rise for sound intensity increase of 1 W/cm² (surface heat generation), but is useful only for rather weak sound below 3 W/cm². The temperature increase depends on the surrounding material. When the sonde is heated by a current through the platinum wire supporting the thermistor, the sensitivity decreases and becomes negative, caused by the cooling of the ultra sound waves. Theoretical considerations help to understand the experimental statements. Distribution of sound in front of a vibrating quartz crystal of 450 kc is given as example for a measurement.

O. Ruediger, Germany

658. Schmitz, W., and Waldick, L., Output measurements of ultrasonic quartz sources (in German), *Z. angew. Phys.* **3,** 8, 281–288, Aug. 1951.

Paper discusses method of determining electroacoustic efficiency, acoustic power output, and equivalent resistance of loaded and unloaded quartz transducers operated in region of 1 mc/sec, with especial reference to effects of transducer housing type on these quantities.

Theoretical portion of paper derives expressions for above quantities in terms of measurable voltage and currents. How the transducer housing affects these quantities is also discussed qualitatively. Paper corrects some previously published expressions for variation of acoustic power output with type of medium being irradiated. Experimental section includes brief description of vacuum-tube voltmeters used to measure input current and voltage to transducer; also described is transformer-coupling network, used for current measurements, which obviates grounding difficulties and compensates for stray currents through distributed capacitances to ground. Measurements are simplified by tuning variable inductor across transducer to resonance, thereby transforming load to pure resistance. Good accuracy is obtained by calibrating the setup with known resistances in place of transducer.

Method discussed provides way of determining acoustic output of transducer under varying conditions by purely electrical measurements, without use of complicated acoustical measuring apparatus. Paul Tamarkin, USA

659. Guptill, E. W., and MacDonald, A. D., The acoustical field near a circular transducer, *Canad. J. Phys.* **30,** 2, 119–122 Mar. 1952.

Authors represent velocity potential as an integral involving Bessel functions, as in the work of King, L. V. [title source, 11

135, 1934] and Pachner, J. [*J. acoust. Soc. Amer.* **23**, 185, 1951]. Taking a smooth variation for the normal velocity of the surface of the transducer, an approximation is given for the average pressure on a similar transducer, coaxial with the first. A similar expression is given for the velocity which is expanded as a series of integrals, each to be evaluated numerically. The convergence of the results is good if the radius of the transducer is greater than 10 times the wave length. Authors state that if the transducers are close together, the phase velocity is greater than in free space. Reviewer believes that this point requires a more detailed investigation. J. M. Jackson, Scotland

660. **Machlup, S., A theoretical model for sound scattering by marine crustaceans,** *J. acoust. Soc. Amer.* **24,** 3, 290–293, May 1952.

Representing marine crustaceans by spherical elastic shells filled with fluid, author studies sound reflecting of latter. He finds that, for incident wave lengths of same order of magnitude as sphere diameter, the behavior for thin shells is similar to that of fluid sphere alone. For longer wave lengths, a correction, given in paper, is necessary. O. K. Mawardi, USA

661. **Junger, M. C., Radiation loading of cylindrical and spherical surfaces,** *J. acoust. Soc. Amer.* **24,** 3, 288–289, May 1952.

Paper presents charts of accession to inertia and radiation resistance for the symmetrical modes of cylindrical and spherical surfaces. Author also derives acoustic power radiated and sound pressure at the surface. The derivation is in function of coefficients of Fourier series or Legendre series for the velocity distribution. O. K. Mawardi, USA

662. **Rimskiĭ-Korsakov, A. V., On sound radiation by a membrane for vibrations of a complex form** (in Russian), *Zh. tekh. Fiz.* **21,** 8, 970–985, Aug. 1951.

A method is suggested for evaluating behavior of a radiator over a range of frequencies above the first harmonic of radiator. This method was used initially by author for evaluating the radiation of sounding boards of musical instruments. Specific problem considered is behavior of membrane excited by sinusoidal force at one point, coefficient of damping being assumed constant over range of frequencies considered, and loss of energy by radiation small compared with loss of energy in membrane itself. Acoustic power radiated by membrane is calculated for exciting force of constant amplitude, transverse dimensions of membrane being large compared with wave length of sound. Equations are derived and graphs presented which express maximum and minimum values of impedance and acoustic power radiated by membrane as functions of frequency.

In an appendix, mechanical impedance of sounding board in form of rectangular membrane with bar and ribs is calculated.

Marie Goyer, England

Ballistics, Detonics (Explosions)

(See also Revs. 554, 555, 628)

663. **Carrière, P., Ballistic perturbations of powder-propulsed projectile during the phase of autopropulsion** (in French), *Mém. Artill. fr.* **25,** 2, 253–360, 1951.

This long paper handles a special but increasingly important part of theoretical exterior ballistics, as may be inferred from its title. It deals with both fin-stabilized and spin-stabilized missiles during propulsion in air. Particular discussion is devoted to effects of (a) an initial impulse couple, (b) lateral wind, and (c) eccentricity of propulsion with respect to the center of mass. A qualitative study is made of the behavior of the projectile at transonic velocities. A number of detailed and informative graphs, and various auxiliary mathematical tables (to four significant figures) are furnished. As author points out, certain reasonable simplifying assumptions are adopted. The aim is to provide the ballistician with means for predicting the nature and magnitude of ballistic perturbations, and thus to equip him to take measures a priori to reduce these to a minimum. In illustrative problems, specific weapons are named and corresponding numerical data provide initial conditions. Unfortunately, the reader finds little evidence that the behavior predicted by so many formulas and with such exactness is substantiated by observation. Possibly security regulations forbid publication of results, to obtain which would, at best, require very elaborate equipment.

A. A. Bennett, USA

664. **Mirabel, H., On modern experimental methods of exterior ballistics in France** (in French), *Actes Coll. inter. Mécan.* **II,** *Publ. sci. tech. Min. Air, Paris* no. 250, 37–50, 1951.

The different experimental techniques currently employed in France for studying external ballistics are reviewed rather briefly by author under the two general headings: (1) Direct methods (model is studied in free flight); (a) ballistic ranges (pressurized and nonpressurized); (b) open range firings. (2) Indirect methods (model is constrained in a moving airstream); (a) supersonic wind tunnels.

The ballistic range technique of employing jump cards (la méthode des panneaux) for measuring amplitude and frequency and its limitations are discussed; alternate methods of making these measurements, using high-speed photography and spark photography, are described. Various open range instrumentation techniques employing the Doppler effect, lateral accelerometers, and surface pressure measurements are discussed. Some of the problems associated with the use of supersonic tunnels to measure aerodynamic forces, pressure distributions, and frequencies are described.

Reviewer feels the paper has interest as a reference concerning the activities of France in the armament field. The methods described do not differ from those currently employed in America, Britain, and Canada, and described in the published literature of those countries. G. V. Bull, Canada

665. **Pugh, E. M., Eichelberger, R. J., and Rostoker, N., Theory of jet formation by charges with lined conical cavities,** *J. appl. Phys.* **23,** 5, 532–536, May 1952.

This paper refines the theory of jet formation from lined conical cavities by assuming the collapse velocity of the cone liner to depend on the original position of any cone element in the cone; the collapse velocities decrease continuously from apex to base in a nonlinear fashion. An analysis is performed using this hypothesis, and a theory of the formation of the complete jet is evolved. In particular, the hitherto anomalous properties of the rear of the jet, which is the most important part of the jet for penetration purposes at large standoff, are shown to be easily explainable consequences of the present theory. It is shown that the collapse velocity gradient produces the lengthening of the jet which produces the deep penetrations. B. W. Augenstein, USA

666. **Eichelberger, R. J., and Pugh, E. M., Experimental verification of the theory of jet formation by charges with lined conical cavities,** *J. appl. Phys.* **23,** 5, 537–542, May 1952.

Paper presents details of experimental results, and, what is more important, a graphical procedure for obtaining the shape of the jet and slug at every instant during the process of jet formation.

Taken together, this and the preceding paper may be said to essentially complete our picture of the macroscopic process of jet formation, and, as such, represent a major advance in the state of knowledge concerning this important process. The experimental corroboration of the new theory is strikingly good, as judged from the results presented. B. W. Augenstein, USA

667. Tsien, H. S., A method for comparing the performance of power plants for vertical flight, *J. Amer. Rocket Soc.* **22,** 4, 200–203, 212, July-Aug. 1952.

A new method of power-plant selection for vertical flight is proposed. It can be used to determine whether the performance of a rocket design can be improved by substituting for the rocket motor a different power plant such as a ramjet. Calculations indicate that there are advantages in using the ramjet, provided the power plant can be made to operate under rapid acceleration and at high altitudes.

From author's summary by S. S. Penner, USA

Soil Mechanics, Seepage

(See also Revs. 452, 456, 682)

668. Tanifuji, S., Studies of the bearing capacity on the subgrade, *Japan Sci. Rev.* **2,** 2, 159–166, Aug. 1951.

Author states that soil tests for road material are oriented toward static measurements, whereas subgrades are subject to dynamic loads, and kinetic measurements are required also. Static tests were carried out with circular plates 30-, 40-, and 50-cm diam on various gravel, stone, and sand-mix subbase underlaid by sandy silt compacted to Proctor optimum density in 3 by 6-m test pits 1.1 m deep. Measurements covered diameter effect and settlement at various depths. Dynamic tests involved dropping a 3-kg steel ball, 80 cm high, into a prepared nest and measuring the impact wave with a pickup connected to an oscilloscope. Results cover velocity of wave in base and soil, absorption coefficient, dynamic modulus of elasticity. Comparative values are given. Robert Quintal, Canada

669. Sichardt, W., Gravel and sand filters in foundation and hydraulic engineering (in German), *Bautechnik* **29,** 3, 4; 72–76, 104–108; Mar., Apr. 1952.

Application of gravel and sand filters is very wide in engineering practice. To avoid errors it is recommended, if possible, to design and build filters on the basis of theoretical considerations.

Author defines the role of filters in dam engineering and gives some modes of their construction with numerical data. Then, with examples of constructed dams, he makes an analysis and draws conclusion as to when and what kind of filters are to be recommended and how they should be constructed.

He interprets the modes of calculation of filters behind iron bulkheads (Larsen) on theoretical basis and with construction details; computes the discharge quantity of waters for different values of the coefficient of permeability of back-fill material k_1, and the required values of coefficient of permeability k_2 of filter material. In this way, it is possible to obtain a diagram for different values of k_1 in relation to the values k_2/k_1, or to obtain the required value of k_2, k_1 being given.

There follows a discussion of the principles of filters with perforated tubes, along with examples of their construction.

D. Krsmanović, Yugoslavia

670. Mallet, Ch., and Pacquant, J., Earth dams (Les barrages en terre) (in French), Paris, Eyrolles, 1951, 345 pp. Fr. frs. 2500.

An introductory chapter is followed by a chapter on the control of flood peaks and on the design of spillways. The third and fourth chapters deal with the theory of seepage and with the design and construction practices for the prevention of piping and of quick conditions. The fifth chapter gives stability-analysis methods of the slopes of a dam and of the soil beneath it. The sixth and last chapter is devoted to the choice of materials and of construction procedures. It is followed by four pages of comments on specific points by Terzaghi. A preface by Terzaghi rightly emphasizes the importance of a semi-empirical approach to such problems.

The book contains much valuable material relating the theory and the practice of the subject. The absence of an index and of a list of symbols is to be regretted. G. P. Tschebotarioff, USA

671. Hvorslev, M. J., and Kaufman, R. I., Torsion shear apparatus and testing procedures, *Wwys. Exp. Sta. Bull.* no. 38, 76 pp., May 1952.

An experimental investigation carried out to determine the shearing resistance of Atlantic muck and Lake Providence clay, using a torsion-ring shear device, was described in an earlier report ["Torsion shear test on Atlantic muck, The Panama Canal. Concluding report." Tech. Memo no. 3-328. Vicksburg, Miss., Aug. 1951].

The present report reviews in brief the principles of the torsional shear method. Its principal merit is that it provides data on the shearing resistance of plastic soils as a function of large shear deformations after failure. The main body of the report gives, in considerable detail, the design and calibration of the apparatus, the preparation of samples, procedure for testing, and the interpretation of results. Eben Vey, USA

672. Johannsen, N., The ultimate bearing capacity of footings on clay, *Tekn. Ukeblad, Tekn. Skr.* no. 2 N, 30 pp., 1951.

Formulas are developed for the computation of the ultimate bearing capacity of footings supported by homogeneous clay-type ($s = c$) soils. The formulas account for any ratio of depth of footing to width of footing, for eccentric loading, and for stratification of the soil above the base of the footing. For convenience, the formulas are expressed in terms of stability numbers, the values of which have been determined and presented graphically as a function of two dimensionless parameters. Application of the formulas is demonstrated by illustrative examples.

R. E. Fadum, USA

673. Taylor, S. A., Estimating the integrated soil moisture tension on the root zone of growing crops, *Soil Sci.* **73,** 5, 331–339, May 1952.

Moisture in unsaturated soils varies continually both with time and depth during growing season. Author emphasizes importance of moisture control. These data are presented by several authors in terms of moisture tension or electrical resistance. Author proposes a general mathematical function expressed by polynomials, with parameters dependent upon time and depth. Then he integrates twice and obtains a theoretical relationship of the integrated soil-moisture tension. As a first approximation, he uses linear polynomials. With the values of integrated soil-moisture tension, author is able to calculate mean values with respect to time and depth. He claims that these values are representative of time and depth variations of moisture tension. Reviewer thinks a single mean value is not enough to accomplish a full description of these variations, but is a good parameter to study soil conditions in which crops are growing. Equations are applied to an example from field statistics during 125 days of growing season, and good concordance is shown between series of values obtained by integrals and summations.

A. Balloffet, Argentina

674. **Bouyoucos, C. J., Methods for measuring the moisture content of soils under field conditions,** Frost action in Soils, Symposium, Nat. Res. Counc. Highway Res. Bd., Spec. Rep. no. 2, 64–74, 1952. $3.75.

Measurement of soil moisture by determining the electrical resistance of porous blocks buried in soil is discussed. Author invented two types of blocks. First type consists of plaster of Paris, and has two linear electrodes. Second type consists of nylon fabric; two sheets of stainless steel serve as electrodes while it is enclosed in a perforated stainless-steel case. Porous material in block exchanges water with soil. Resistance of block thus depends on soil-moisture tension. It is measured with a special a-c Wheatstone bridge. Characteristics of blocks and laboratory calibration methods are treated.

Other methods for measuring soil moisture are mentioned; many references are given. D. A. de Vries, Holland

Micromeritics

675. **Saxton, R. L., and Ranz, W. E., Thermal force on an aerosol particle in a temperature gradient,** *J. appl. Phys.* **23,** 8, 917–923, Aug. 1952.

A brief discussion is given of existing theories of radiometer forces on aerosol particles, notably of the work of Cawood, Einstein, and Epstein. Radiometer forces may be defined as forces other than those of convection which act on a body suspended in a gas not in thermal equilibrium. The work of Epstein, which takes account of the kinetic theory, hydrodynamics, and theory of heat exchange involved in the problem, results in $F = (-9\pi D\mu^2/2\rho T)\,[k_a/2k_a + k_i]G$, where F is the radiometer force on a particle of diameter D and thermal conductivity k_i in a gas of viscosity μ, density ρ, thermal conductivity k_a at mean absolute temperature T. G is the temperature gradient far from the particle, while $[3k_a/k_a + k_i]G$ is the temperature gradient in the vicinity of the particle.

Authors measured F experienced by paraffin oil and castor oil particles ranging in diameter from 0.481 to 2.16 μ, suspended in air at room temperature. Millikan's oil-droplet method was used. Aerosol particles were formed in an oil atomizer, and charged in a passage through a corona discharge. They were then placed into an air gap, 3 mm wide, between two horizontal condenser plates, where their vertical motion under the influence of gravity and different vertical electrostatic fields could be observed microscopically. Particle mass and charge could be deduced. The upper plate was then heated, and the resulting radiometer force was compensated by a measured change in the electric field. The temperature gradients used ranged from 18.4 to 140 C cm^{-1}. The results obtained from about 60 detailed observations on 40 particles were compared directly with Epstein's equation. While individual deviations were great (average about 18%), the mean values agreed reasonably well with the theory. Comparison with the other theories is much less satisfactory.

Experiment probably allows assertion of the proportionality of F to D and G; in reviewer's opinion, neither experiment nor the analysis of the data substantiates unambiguously the other terms of the Epstein equation. W. Hitschfeld, Canada

Geophysics, Meteorology, Oceanography

(See also Rev. 524)

676. **Hollmann, G., On the dynamics of stationary atmospheric pressure fields** (in German), *Abh. Meteor. Dienst. Deutsch. Demok. Repub.*, no. 12, Akademie-Verlag, Berlin, 32 pp., 1952.

The importance of stationary pressure fields is well known in all forecasting theories. Stationary conditions have previously been investigated by Ertel and Rossby for a barotropic, frictionless atmosphere. In this paper, baroclinicity and ground friction are also taken into account. Equations are simplified with help of the quasigeostrophic assumption, and friction is introduced with the simple Guldberg-Mohn equation. Vertical velocity is necessarily maintained in the system. The result is given in the form of a first-order integral condition for the pressure field, and discussed for various types of fields. It is shown that stationary pressure fields, e.g., cellular fields, are possible if there is a meridional temperature gradient. A stationary high can only be maintained if the masses lost in the frictional layer are replaced at great height. The axis of the high should then be inclined toward the west and the streamlines should be cyclonic at great height—as is really observed. Horst Merbt, Sweden

677. **Kiveliovitch, M., Some considerations on the geostrophic wind** (in French), *J. sci. Météor.* **4,** 14, 61–66, Apr./June 1952.

Author starts with the expressions of the components (in three dimensions) of the geostrophic wind, and then derives the analytic form for the pressure and density as functions of the coordinates of space and time.

From author's summary by P. F. Byrd, USA

678. **Hinkelmann, K., The atmospheric mechanism of the formation of the daily pressure wave** (in German), *Meteor. Rdsch.* **5,** 3/4, 41–45, Mar./Apr. 1952.

The method of E. Lingelbach [title source, **4,** 209, 1951] of computing the pressure tendency on the ground from simplified equations of quasistatic motion in the atmosphere is criticized, and the disagreement with the observation is explained by a questionable convergence of the iteration process used. Author modifies this method and uses as an example the problem of atmospheric processes caused by the daily variation of ground insolation. He starts from similar system of equations, with two additional terms—the divergence caused by the friction, and a term defining the nonadiabatic heating, given by a harmonic function of the zonal coordinate and of the time. The solution is assumed in the form of Fourier series which, substituted in the equations, yields a system of integral equations for the coefficients in these series. The integral equations are transformed by differentiation into ordinary inhomogeneous differential equations. These have been solved for some special numerical values of the parameters, and the coefficients for the first harmonics found negligible with respect of those of the principal mode. Lingelbach's iteration method, though, gives a completely different result. Z. Sekera, USA

679. **Sartor, J. D., Katz, I., Katz, R. E., A mobile method for measuring atmospheric diffusion,** *Bull. Amer. meteor. Soc.* **33,** 5, 188–194, May 1952.

Article describes technique developed at Naval Research Laboratory for calculating eddy diffusion coefficients in free atmosphere to heights of several hundred feet from measurements of drift and spread of smoke puffs. Apparatus consists of smoke-puff generator and wiresonde (resistance thermometer and hygrometer) lifted by tethered kiting-balloon. Puffs are produced by charges of black powder contained in pill boxes and fired by electrically heated filaments. Interlock switches actuated by detonations serve to arm successive charges so that only two firing switches are required. Smoke puffs are tracked by ground-based theodolite and cameras to measure wind speed and expansion of puff. Eddy diffusion coefficients are calculated by method of O. G. Sutton [*Proc. roy. Soc. Lond.* (*A*) **135,** 143–165, 1932].

Reviewer agrees with authors that major weakness is difficulty of determining exact limits of puff by optical means, especially if background changes. Short time of observation (10 sec to about a minute) may give nonrepresentative result; several successive observations should be averaged. Technique is valuable tool for radio-scattering and air-pollution studies.

E. W. Barrett, USA

680. Inoue, E., The application of the turbulence theory to the large-scale atmospheric phenomena, *Geophys. Mag., Tokyo* **23,** 1, 1–14, Dec. 1951.

Author summarizes his previous work and other known results on spectra of velocity, pressure, and temperature for small, intermediate, and large wave numbers, and suggests that some of these results may be applied to large-scale turbulence in the atmosphere. Most of the results are based on dimensional arguments and physical hypotheses. No observations are given to substantiate these hypotheses; e.g., his negative seven-thirds power law for temperature spectrum, in the intermediate range of wave numbers, is at variance with negative five-thirds law derived by Obukhov [AMR **3,** Rev. 2442] and Corrsin [AMR **4,** Rev. 3644] for the same range of wave numbers.

M. S. Uberoi, USA

681. Shepard, F. P., and Inman, D. L., Nearshore circulation, Proc. First Conf. Coastal Engng., Long Beach, Calif., 1950, 50–59, 1951.

Paper studies nearshore currents in relation to a variety of coastal types and submarine configurations. In case of straight beaches with parallel contours, observed velocities of longshore current are compared with theoretical velocity based on momentum considerations. Discrepancy is attributed to rip tides, cell-like circulation in nearshore systems, variable friction coefficient, and fluctuations in longshore currents. In cases of crescentic beaches or those bordered by irregular submarine topography, or where submarine canyon heads approach coast, theoretical approach is impractical. Motion is complicated by localized points of wave convergence, and divergence and currents might oppose direction of wave approach. Points, breakwaters, and piers similarly influence circulation patterns.

Herbert Riehl, USA

682. Homma, S., Some problems on the thermoelastic deformations of the earth's crust, *Geophys. Mag., Tokyo* **23,** 2, 125–144, Jan. 1952.

Two problems are studied theoretically: (1) Distribution of strain in a tunnel due to the variation of temperature at the earth's surface outside the tunnel; (2) stresses in the earth's crust due to the variation of surface temperature over the land (near a boundary of land and ocean); the case of land between two oceans is included. Both problems are treated two-dimensionally, assuming the validity of elasticity theory. Results of the second investigation indicate that diurnal and annual temperature variations cause stresses too small to produce any trigger action for earthquakes.

A. D. Topping, USA

683. Goody, R. M., A statistical model for water-vapour absorption, *Quart. J. roy. meteor. Soc.* **78,** 336, 165–169, Apr. 1952.

A statistical model of a water-vapour absorption band is discussed, and comparison with computations made by Cowling shows that it provides a very accurate account of the average transmission over narrow frequency bands. The model can be used to compute the atmospheric transmission by water vapor under conditions of meteorological importance which were not treated by Cowling.

From author's summary by R. J. Mindak, USA

684. Ando, T., Energy of anticyclone, *Pap. Meteor. Geophys.* **2,** 3/4, 268–273, Dec. 1951.

The potential and kinetic energy of various anticyclones near Japan are computed largely from surface observations. Author concludes approximately 43% of decrease in potential energy due to subsidence will be converted into kinetic energy. Method of computation includes numerous implicit approximations, some of dubious validity.

George S. Benton, USA

685. Stümke, H., Changes of state through large space heat addition in the interior of an atmosphere initially at rest (in German), *Meteor. Rdsch.* **5,** 1/2, 1–7, Jan./Feb. 1952.

The equations of axial motion about the vertical axis considering the space heat addition in the interior of a frictionless atmosphere initially at rest are derived. These equations of motion are solved for a special case, and the resulting solutions for development of wind, pressure, and temperature are illustrated graphically, giving proper values for each parameter.

Reviewer believes that author intended to show the computations following the classical local heating theory on the cyclogenesis, which is no longer the current idea, although the treatment from the aerodynamical point of view gives a quite fresh impression for most meteorologists and will serve to supply deeper insight into the development of tropical cyclones.

H. Arakawa, Japan

Lubrication; Bearings; Wear

(See also Rev. 549)

686. Späth, W., Basic questions of wear (in German), *ZVDI* **94,** 25, 829–832, Sept. 1952.

Examples are given which show how diagrams concerning the wear under various conditions can be simplified, depending upon the choice of variable. For example, the critical hardness below which the wear of a pantograph of a crane is negligible, is best illustrated in a diagram in which the coordinates are the wear for a certain distance of travel and the reciprocal of the Brinell hardness. Other examples illustrating the method of presenting data are also given.

E. I. Shobert, II, USA

687. Perret, H., Vibrations in roller bearings with statically determinate supports (in German), *VDI-Forschungsheft* 434, 17–28, 1952.

Vibrations, excited in revolving roller bearings, are one of the main causes of the noise of motion. As a special problem of the studies on elastic-mechanical and geometrical relations in roller bearings, conditions for generation of vibrations are treated for the special case that no more than two rollers support the load at the same time (statically determinate supports). This case occurs frequently at small load, large clearance, and low number of rollers. Calculated are the elastic deflections of the centers of roller paths both parallel and perpendicular to the radial load. At running of the bearing, these deflections work kinematically as excitation of vibrations. Conditions may be created for these vibrations on which even an increased accuracy of bearing production has no influence. For some conditions which may be achieved by simple design measures and fitting of the bearing, the vibrations reach a minimum.

W. Kochanowsky, Germany

688. Johnson, R. L., Swikert, M. A., and Bisson, E. E., Investigation of wear and friction properties under sliding conditions of some materials suitable for cages of rolling-contact bearings, *NACA Rep.* 1062, 12 pp., 1952.

On the basis of wear and resistance to welding only, the cast

irons (nodular iron and gray cast iron) were the most promising materials investigated; they showed the least wear and the least tendency to surface failure when run dry, and when boundary lubricated they showed the highest load capacity. On the basis of mechanical properties, nodular iron is superior to gray cast iron.

Under dry sliding conditions, bronze had the lowest friction coefficient, although the material was subject to surface failure at high sliding velocities and at high loads. The results with brass, beryllium copper, and aluminum were poor, and these materials do not appear, with regard to friction and wear, to be particularly suited for cages. From authors' summary

689. **Johnson, R. L., Swikert, M. A., and Bisson, E. E., Wear and sliding friction properties of nickel alloys suited for cages of high-temperature rolling-contact bearings. I. Alloys retaining mechanical properties to 600° F. II. Alloys retaining mechanical properties above 600° F,** *NACA TN* 2758, 2759; 30 pp., 30 pp.; Aug. 1952.

Wear and sliding-friction properties of a number of nickel alloys operating against hardened SAE 52100 steel were studied. These alloys include "L" nickel, wrought monel, cast monel, cast modified "H" monel, cast "S" monel, Invar, Ni-Resist 3, and Nichrome V. Some of the alloys studied may be useful as possible cage materials for high-temperature, high-speed bearings for aircraft turbines, or for bearings to operate in corrosive media.

On the basis of wear and friction properties, Ni-Resist 3, modified H monel, and Invar were the best materials studied, although they did not perform as well as nodular iron. The L nickel performed well with light loads but was not effective at higher loads when the surface film broke down.

In part II, the alloys studied were cast beryllium nickel, heat-treated beryllium nickel, cast Inconel, Nimonic 80, Inconel X, Refractalloy 26, and Discaloy. Some of the alloys studied may be useful as material for cages of rolling-contact bearings that operate at high speeds with temperatures above 600 F in projected aircraft turbine engines, or for bearings that operate in corrosive mediums. On the basis of wear and friction properties, cast Inconel performed very well in these experiments and compares favorably with nodular iron. Nimonic 80 also showed promise as a possible cage material.

From authors' summary

690. **McKee, S. A., Oil flow in plain journal bearings,** *Trans. ASME* **74,** 5, 841–845, July 1952.

Correlation of oil flow data for journal bearings is presented. Graphical analysis is used to separate total flow into two parts, one related to load, and the other to oil pressure. Circumferential groove, axial groove, and single oil hole are considered. No consideration is given to length-diameter ratio.

E. F. Macks, USA

Marine Engineering Problems

(See also Revs. 523, 544, 546)

691. **Strscheletzky, M., Hydrodynamic fundamentals for the analysis of ship propellers [Hydrodynamische Grundlagen zur Berechnung der Schiffsschrauben],** Karlsruhe, Verlag G. Braun, 1950, 257 pp. $3.

Author considers the three-dimensional flow of a propeller with a finite number of blades for the case of axisymmetrical inflow. The effect of the propeller is determined from an integration over the equivalent vortex system on a basis of the Biot-Savart integral, replacing the blades by lifting surfaces. Relative to the free vortexes, the velocity components are deduced for regular helical lines and are expressed by induction factors (as defined by Moriya). Corrections are given for the influence of small differences from regular helical lines both with respect to the radius (contraction) and to the pitch angle. A numerical example for the velocity field of helical sheets, which follows by an integration over that of the vortex lines, is based on charts for the induction factors which have been calculated for $z = 3$. These charts are not included in the book but can be obtained from the author. Relative to the bound vortexes of the lifting surfaces, expressions for the velocity components are derived when replacing the continuously changing bound vortexes by discontinuous radial vortexes. The numerical values of fundamental functions which are independent of both the loading and of the shape of the blade are, again, not represented. From the velocity fields of both the free and bound vortexes, the camber of the flow on the lifting surfaces is determined. Corresponding to a numerical example, the effect of the free vortexes on the camber is greater than that of the bound vortexes and, further, the camber correction is such that, for shock-free flow, the section of the propeller is less cambered than the isolated section in two-dimensional flow in order to produce equal lift (these results do not appear to agree with those from the theory by Ludwieg and Ginzel). Considerations on the optimum circulation for free-running propellers follow and, for a certain case, the optimum distribution for lifting lines is compared with that for lifting surfaces. For the latter, which is numerically laborious, the circulation is somewhat greater near the hub and smaller near the tip. In both of these cases, the influence of drag on the distribution is negligible. After considerations on the suitable shape of sections within the propeller flow and the determination of their thickness shape from sink-source distributions, a synopsis relative to the design of a propeller from the three-dimensional theory concludes the book.

H. W. Lerbs, USA

692. **Weinblum, G. P., The practical use of theoretical studies in wave resistance,** *J. Amer. Soc. nav. Engrs.* **64,** 2, 251–258, May 1952.

Author describes in very broad terms the assumptions on which the linearized theory of wave resistance is based. Practical results of this theory when applied to ships are indicated. No mathematical theory is given. Article has been published previously in *Mar. Eng. Ship Rev.* 49–52, Oct. 1951.

J. K. Lunde, Norway

693. **Prohaska, C. W., Influence of ship form on transverse stability,** *Trans. Instn. nav. Arch. Lond.* **93,** 258–284, 1951.

In a previous paper [AMR **1**, Rev. 1288], author gave a chart for coefficient of transverse stability C_{BS} as a function of ship parameters. In present paper, results of calculations for series of 42 ship forms are compared against predictions from chart. It is found that chart requires corrections for effect of additional form parameters. Consequently, a new method for rapid calculation of stability curves has been developed.

In the new method, stability curves are approximated by trigonometric series. This method has the advantage that influence of different form parameters is made evident. Tables to facilitate the application of the method are included.

L. Landweber, USA

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